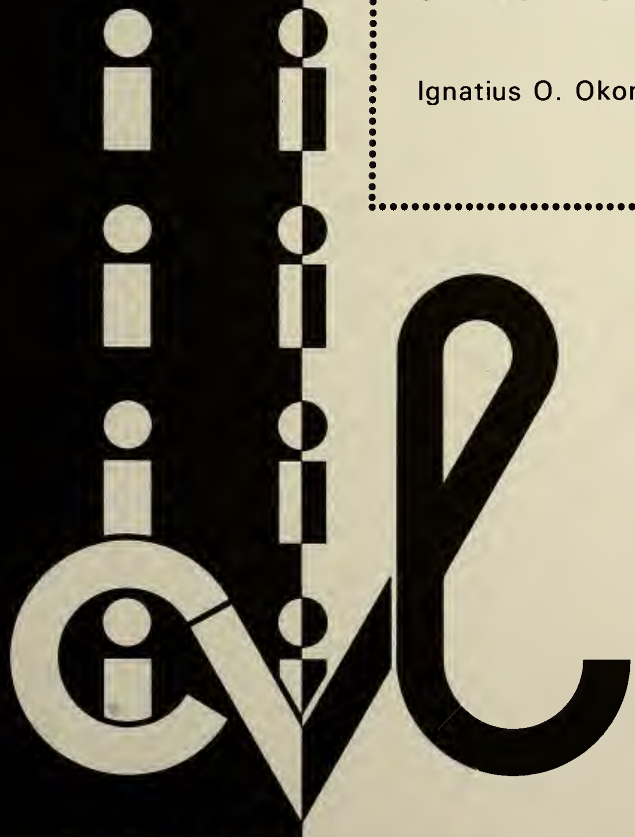
SCHOOL OF
CIVIL ENGINEERING

INDIANA
DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY
RESEARCH PROJECT
JHRP-85-19

ENGINEERING SOILS MAP OF ORANGE COUNTY, INDIANA

Ignatius O. Okonkwo



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Final Report

ENGINEERING SOILS MAP OF ORANGE COUNTY, INDIANA

To: H.L. Michael, Director
Joint Highway Research Project

December 4, 1985

Project: C-36-51B

From: Robert D. Miles, Research Engineer
Joint Highway Research Project

File: 1-5-2-77

The attached final report entitled "Engineering Soils Map of Orange County, Indiana" completes a portion of the long-term project concerned with the development of a county engineering soils map of each of the 92 counties of the State of Indiana. This is the 77th report of the series. The report was prepared by Ignatius O. Okonkwo, Research Assistant, Joint Highway Research Project.

Mr. Okonkwo developed the engineering soils map using aerial photographs, available literature, available soil borings, and field studies. Generalized soil profiles of the major soils of each land form - parent material area are presented on the engineering soils map included. The map and report should be useful in planning and developing engineered facilities in Orange County.

Sincerely,

Robert D. Miles

Robert D. Miles, P.E.
Research Engineer

RDM/rrp

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Final Report

ENGINEERING SOILS MAP OF ORANGE COUNTY, INDIANA

by

Ignatius O. Okonkwo
Research Assistant

Joint Highway Research Project
Project No: C-36-51B
File No.: 1-5-2-77

Prepared as Part of an Investigation

Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

in cooperation with

Indiana Department of Highways

Purdue University
West Lafayette, Indiana

December 4, 1985

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The author is indebted to the other students with whom he had the pleasure to work on this project, including Ed Gefell and John Tyree, for their friendship and technical assistance. Special recognition is given to Xiao Gong Wang and Mrs. Margarita Gomez for their excellent work in drafting the engineering soils map, and finally to Dawn Leverknight, Rita Pritchett and Julia Jordan for their secretarial skills.

ENGINEERING SOILS MAP
OF
ORANGE COUNTY, INDIANA

INTRODUCTION

The engineering soils map of Orange County, Indiana, which accompanies this report, was prepared primarily by interpretation of aerial photographs using accepted principles of observation (1)*. Additional information was obtained from the bedrock geology map of Vincennes Quadrangle (2). The Agricultural Soil Survey Report for the County was used to compile the subsurface profiles (3). Several field trips were made to clarify the soil boundaries that were difficult to establish from the airphotos. Field evidence of the geotechnical problems experienced within the county was also collected during the trips. The aerial photographs were taken in February and April, 1938 for the U.S. Department of Agriculture and have an approximate scale of 1:20,000.

Standard symbols developed by the staff of the Airphoto Interpretation Laboratory in the School of Civil Engineering at Purdue University, were used to identify landform - parent material associations and soil textures on the engineering soils map. The text of this report includes a general description of the study area, descriptions of the engineering soil types, and a discussion of the engineering problems associated with the soils and bedrock found in Orange County, Indiana. Appendix A contains

---

* note: numbers in parenthesis footnote references.

boring logs and laboratory test data on specific soil samples.

The predominant agricultural soils associated with each land form - parent material class are covered in the discussion of the engineering soils unit of the county. Information on the engineering properties of these soil series is listed in Appendix B.

Soil samples were collected to verify the soil profiles shown on the map. The profiles were constructed from the Agricultural Soil Survey Report for Orange County, and from observations of soil data along various state and county roads, in addition to site investigation borings.

DESCRIPTION OF THE AREA

General

Orange County is located in south-central Indiana as shown in Figure 1. A photomosaic of Orange County is shown in Figure 2. Orange County is bounded by Lawrence County on the north, Washington County on the east, Crawford County on the south, and Martin and Dubois Counties on the west. The county extends about 20 miles from north to south and about 20 miles from west to east, with an area of 405 square miles (1,049 sq. km.) (3). Total population according to the 1980 census (4) is 18,677 with 9,818 (53 percent) residing in rural areas. Paoli, the county seat, with a population of 3,637, is near the center of the county.

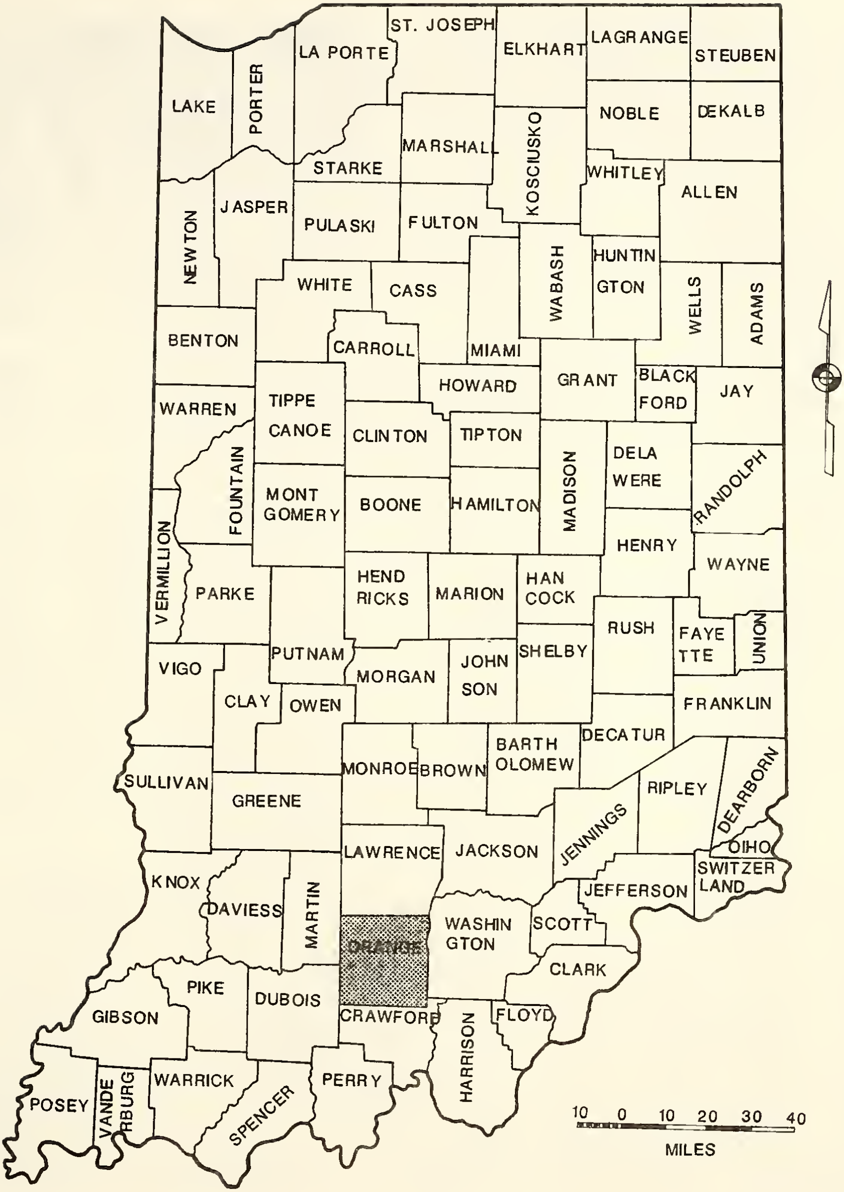
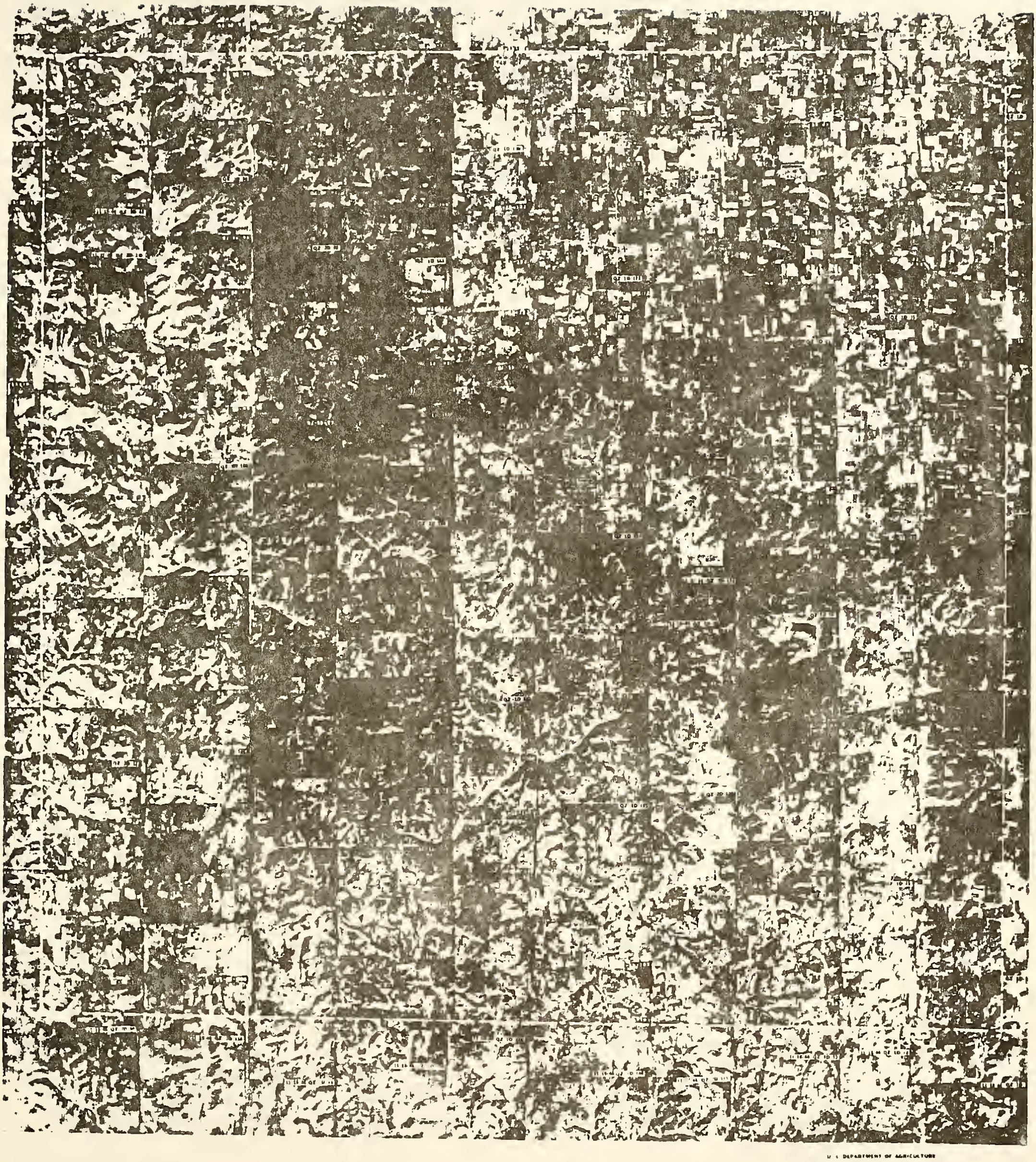


Figure: 1. Location Map of Orange County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ORANGE COUNTY INDIANA
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GRAPHIC SCALE IN MILES PHOTO INDEX

Figure: 2. Photomosaic of Orange County, Indiana.

The 1974 U.S. Agricultural Census (5) indicates that about 160,000 of the 259,200 acres is classified as farmland. About 50 percent of the 160,000 acres is cropland, 23 percent is wooded, and the remainder is in pasture. Limestone quarries exist in the county and produce limestone aggregates and agricultural lime. In the past, stones were quarried and polished and shipped as far as New York and England.

Climate

The climate of Orange County is characterized by well-marked seasonal changes in temperature, with relatively hot summers and cold winters. Sudden changes in the daily temperatures are common. Average annual precipitation is about 45 inches (114 cm.). Of this, 24 inches (61 cm.) or 55 percent usually falls in April through September (3). Average daily temperature ranges from 32^o F in January to 73^o F in July (3).

The expected average seasonal snowfall is 17 inches (43 cm.). Average relative humidity in mid-afternoon, during the summer months is about 60 percent (3).

Other climatological data compiled at Paoli for the period 1951 to 1974 (3) is presented in Table 1.

Physiography

The physiographic map of Indiana, as shown in Figure 3, reveals that two subsections are found in Orange County, the Mitchell Plain and the Crawford Upland. They are part of the

TABLE 1. TEMPERATURE AND PRECIPITATION DATA

[Recorded in the period 1951-74 at Paoli, Indiana] (3)

Month	Temperature						Precipitation				
	Average daily maximum	Average daily minimum	Average	2 years in 10 will have--		Average number of growing degree days[1]	Average	2 years in 10 will have--		Average number of days with 0.10 inch or more	Average snowfall
				Maximum temperature higher than--	Minimum temperature lower than--			Less than--	More than--		
	°F	°F	°F	°F	°F	Units	In	In	In		In
January-----	40.3	19.0	29.7	69	-14	0	3.55	2.00	4.80	7	5.3
February----	44.1	21.2	32.7	71	-10	7	3.23	1.52	4.61	7	4.0
March-------	52.6	29.2	40.9	81	7	41	4.64	2.50	6.38	9	3.8
April-------	66.4	41.0	53.8	86	20	160	4.38	2.65	5.93	9	.2
May---------	75.7	49.6	62.7	92	28	400	4.47	2.70	6.04	8	.0
June--------	83.6	58.7	71.2	97	40	636	4.34	2.39	5.92	8	.0
July--------	87.0	62.3	74.7	98	45	766	4.45	2.77	5.95	7	.0
August------	86.5	59.7	73.2	98	43	719	3.25	1.72	4.49	5	.0
September--	80.6	53.0	67.0	95	33	510	2.87	1.45	4.02	5	.0
October-----	69.9	40.2	55.0	88	20	194	2.55	1.06	3.74	5	.0
November----	54.7	30.7	42.8	80	8	9	3.65	2.11	4.91	7	1.5
December----	43.7	23.1	33.4	70	-6	14	3.50	1.84	4.85	7	2.6
Year------	65.4	40.6	53.1	101	-16	3,456	44.88	38.98	49.66	84	17.4

[1] A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minimum daily temperatures, dividing the sum by 2, and subtracting the temperature below which growth is minimal for the principal crops in the area (50° F).

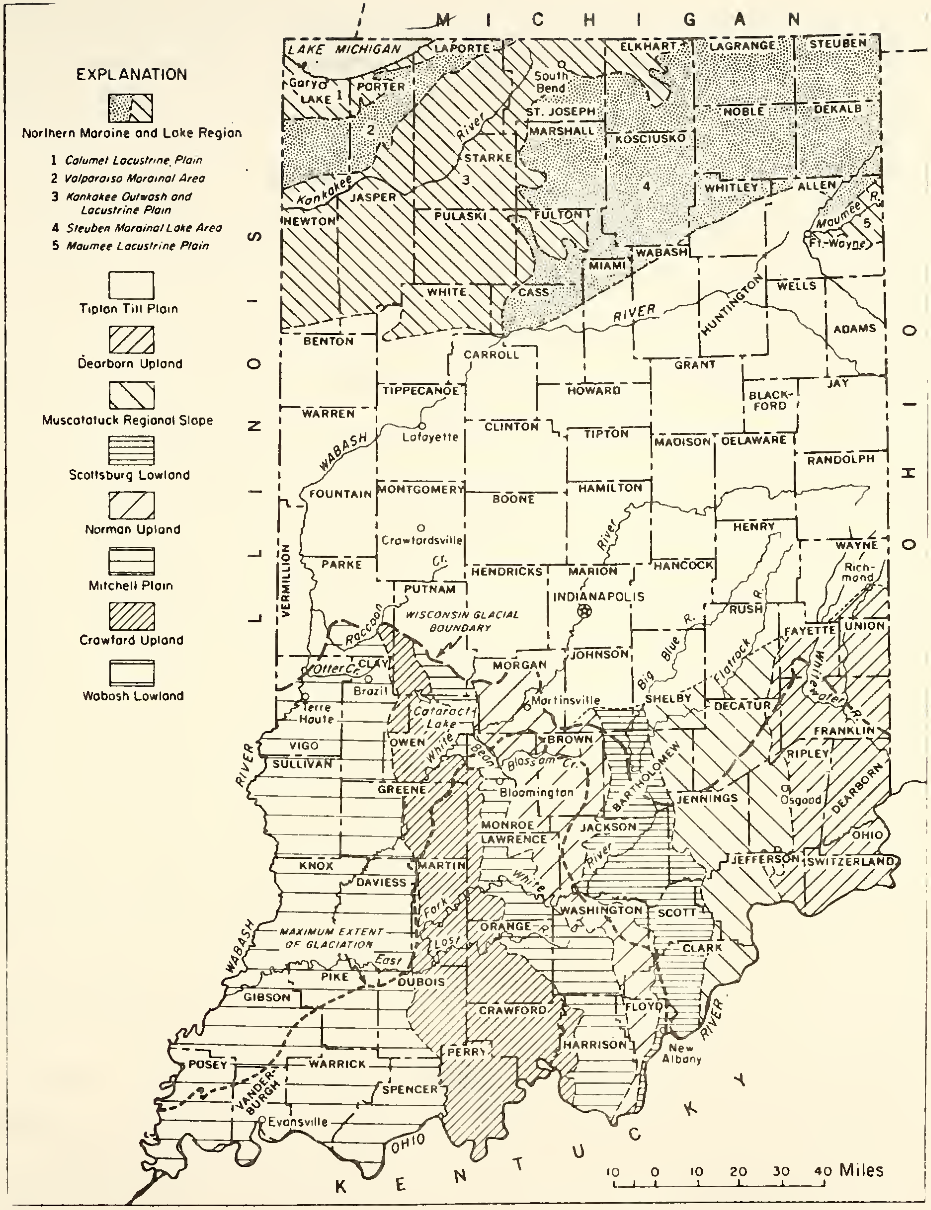


Figure: 3. Physiographic Map of Indiana.

(After Reference (6))

Highland Rim Section of the Interior Low Plateau Province (6). The northeastern part of the county lies on the Mitchell Plain, and the southern and western part on the Crawford Upland.

The Mitchell Plain is an area of low relief with an apparently low westward-dipping slope of about 20 feet per mile (3.8 m per km). The Mitchell plain in Orange county exhibits distinct karst topographic features, especially near Orleans and south of the Lost River. The Mitchell plain is formed on the dip slope of a moderately thick sequence of middle Mississippian limestones (see Figure 3). West of this plain lies the Crawford Upland, composed mostly of interbedded sandstone, siltstone, shale and limestone. Differential erosion and weakening of the diverse lithologic units in this area has produced a deeply dissected plateau marked by great diversity of topographic features. This is conspicuous where the shale hills are severely eroded. Most of the ridges are capped by hard sandstone. In the south central and western parts, deeply incised valleys are common. The Crawford Upland rises approximately 160 feet (49 m) above the adjacent Mitchell Plain.

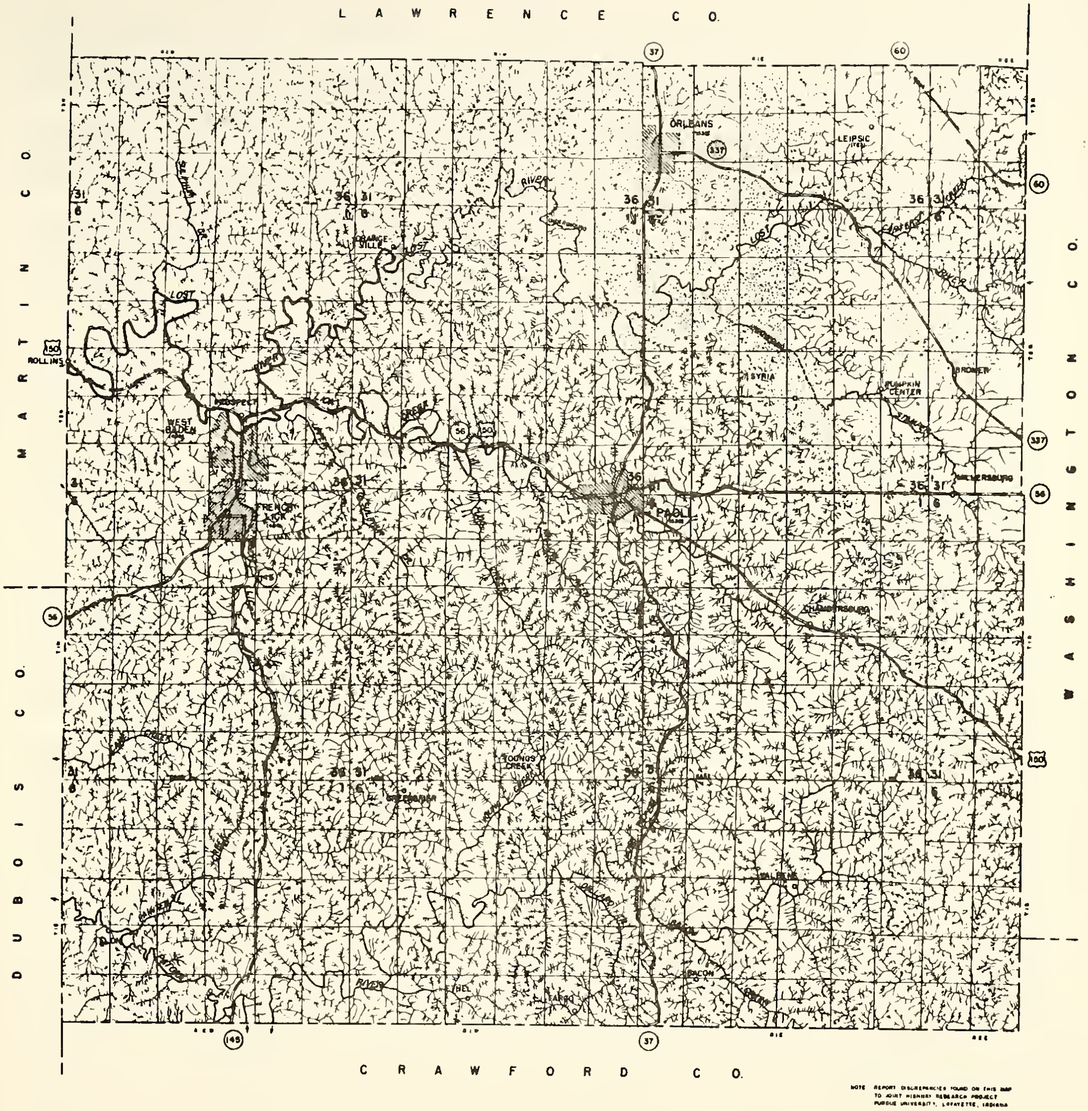
Drainage Features

Orange county is characterized by three major drainage watersheds (6). The northern half of the county is in the East Fork subdivision of the White River basin, the southeast corner is in the Minor Ohio basin, and the remainder is in the Patoka river watershed. The drainage map of the county is shown in Fig-

ure 4 (7). The primary river systems are the Patoka River and the Lost River.

Orange county is dissected by many small streams that empty into either the Patoka River or the Lost River. The general trend of drainage is westerly. Both surface and underground drainage systems are developed in the county. Surface drainage is best developed along the principal stream valleys of the. Patoka River and the western section of the Lost River. Underground drainage is developed primarily on the Mitchell Plain in the north eastern part of the county.

Drainage is largely controlled by the physiographic setting of the county. In the Crawford Upland section of the county, in the western part, the drainage patterns are relatively fine-textured rectangular form due to intensive weathering and dissection of the shale and sandstone units. Low order streams exhibit a fine rectangular form, while the higher order streams are angular. The Lost River in the northern part of the county has a very meandering course. The Lost River valley is narrow, as a result of flow through the more resistant limestone rock units. This control produced a narrow flood plain. Also, the Patoka River has a narrow valley in the southern part of the county. Most of the valley of the Patoka River is occupied by the man-made Patoka Lake. French Lick Creek, in the south-central region, flows northerly to join with the Lost River. Lick Creek shows the effects of rock control by its meanders. Sulphur Creek drains the northwest part of the county and flows south to join



DRAINAGE MAP

ORANGE COUNTY

INDIANA

Figure: 4. Drainage Map of Orange County.

(From Reference (7))

Lost River to the northwest of West Baden. Upper Sulphur Creek, Log Creek and Willow Creek flow northward to join the Lost River between Paoli and West Baden. Painter Creek, Young Creek, Dillard Creek, Hogs Defeat Creek, and Bacon Creek are tributaries to the Patoka River which flows westerly and joins the Wabash River in Gibson County.

The Mitchell Plain exhibits classic karst development with little surface drainage. Swallow-hole type drainage is common. Lost River flows as a surface stream in the north eastern part of the county until just north of Paoli, it disappears and flows in a subterranean channel until it emerges as a surface stream a few miles south of Orangeville in the Crawford Upland. South east of this location another small tributary of the Lost River disappears underground over a distance of two miles, reappearing again near Bromer. The main tributary which flows southwesterly continues as a surface stream from the neighboring Crawford County. Lost River is the best example of subteranean drainage occurring in the limestone bedrock area of the state.

A small area in the southeastern part of the county is drained by streams that empty into the Blue River in Crawford County. There are no natural lakes in the county except that sinkholes sometimes are plugged to form small ponds. Some farm-ponds exist within the county. Two distinct man-made lakes in the county are Tucker Lake, which is formed on the tributary of the French Lick Creek, and Patoka Lake which is a large reservoir on the Patoka River in the southwestern corner of the county.

Topography

Orange County is marked by gently rolling to extremely rolling to blocky topography. The north-central part, on the Mitchell Plain, is generally undulating. The southern and western parts are highly dissected with many ridges and valleys. The nearly level surfaces are the flood plains associated with creeks and rivers. The highest elevation, about 970 feet (295.66 m) above sea level, is in the south-eastern part of the county (9) about two miles southwest of Fargo. The lowest elevation, about 470 feet (143.26 m) above sea level is at the point where the Lost River flows westward into Martin County. The topographic map of Orange County is shown in Figure 5 (9).

The Lost River valley is deeply incised and steep walled especially in the western part of the county. The flood plain of Lost River is quite narrow over most of its length and it is subterranean for about 30 percent of its length. The Patoka River is aggraded in the southwest corner of the county and is flooded by Patoka Lake. The Patoka River valley is relatively flat bottomed with steep-sided valley walls. Alluvial stream terraces are found throughout the valley. Rock benches are found also within the major river and some minor river valleys.

General Geology

The surficial geology of Orange County consists predominantly of bedrock of Paleozoic age and unconsolidated materials of the Quartenary (Pleistocene) period. Bedrock in the county

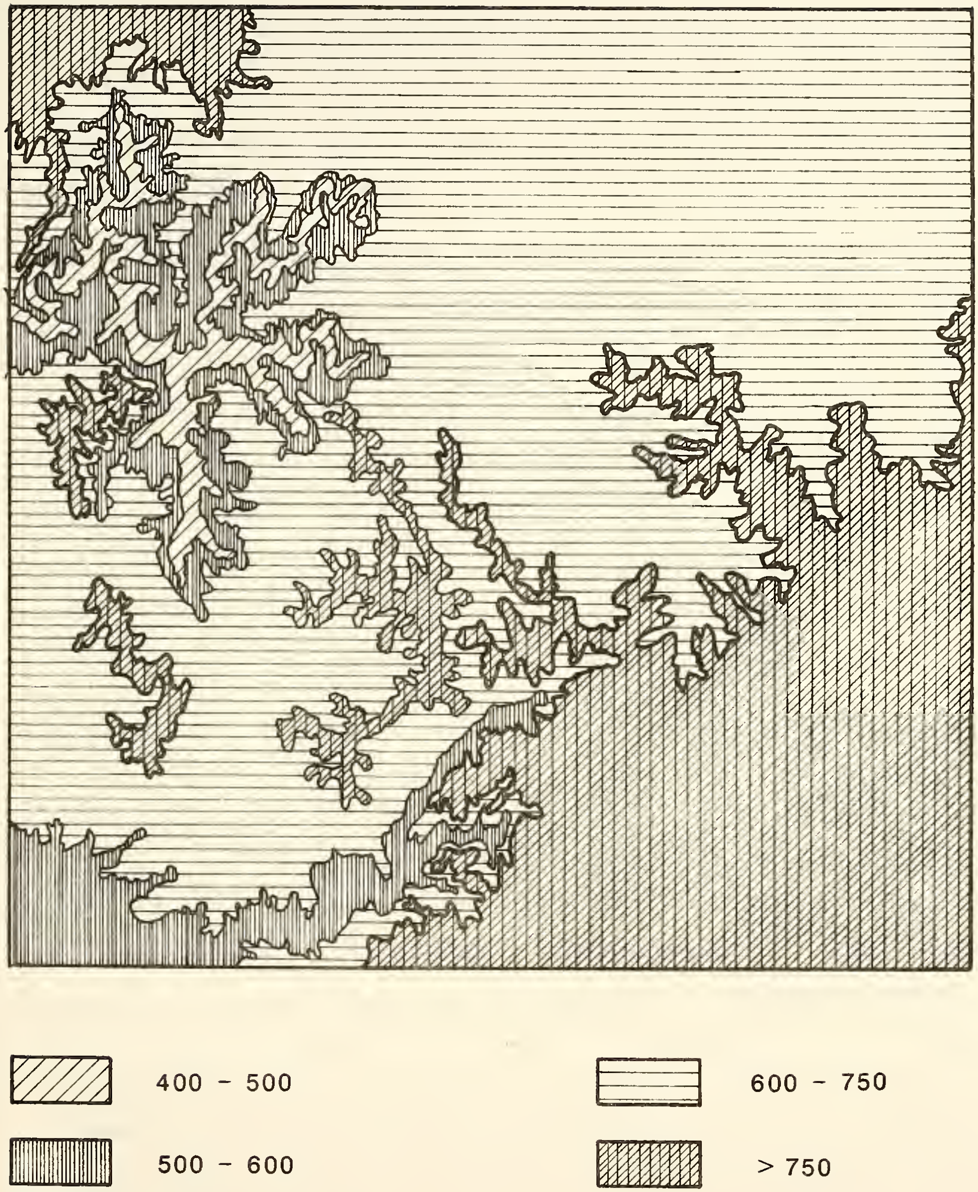


Figure: 5. Topographic Map of Orange County
(After Reference (9))

includes one group of formations of Pennsylvanian age and four groups of formations of Mississippian age (2). The bedrock lithology in the east (the Mitchell Plain) is limestone, changing gradually to limestone and interbedded sandstone, siltstone, limestone and shale (Crawford Upland) in the west.

Most of the unconsolidated deposits are of recent time. These are comprised mostly of alluvium, but include some colluvial and paludal deposits of the Martinsville formation (2). Along terraces of major streams and rivers and their larger tributaries, a few lacustrine and colluvial deposits associated with Illinoian glaciation are mapped and are identified with the Prospect Formation of Indiana (2). The Mount Carmel fault system is a north-south trending fault and is about five miles from the northeastern part of the county, near Lawrence County.

Bedrock Geology

The areal distribution and type of bedrock in the county is shown in Figure 6 (2). Also, the columnar section of the rocks in the area is shown in Figure 7 (2). For clarity, the rock units are grouped into two types, corresponding to the two physiographic subsections found in the county, the Mitchell Plain and the Crawford Upland.

The Mitchell Plain contains the oldest rocks in the county and are mostly series of limestones of Mississippian Age. The oldest is the Blue River Group containing the St. Louis, Ste. Genevieve and Paoli Limestone Formations. They are generally

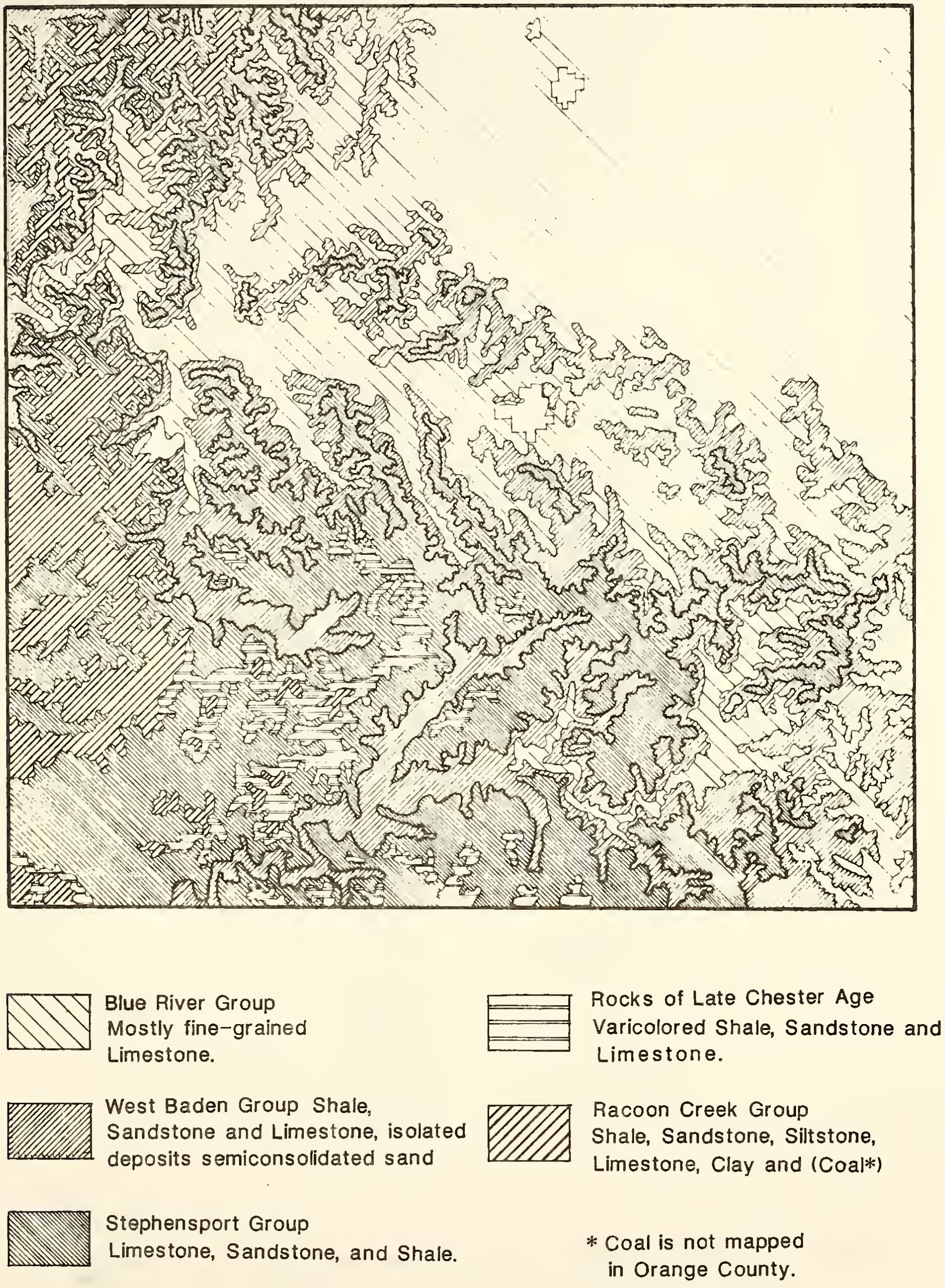
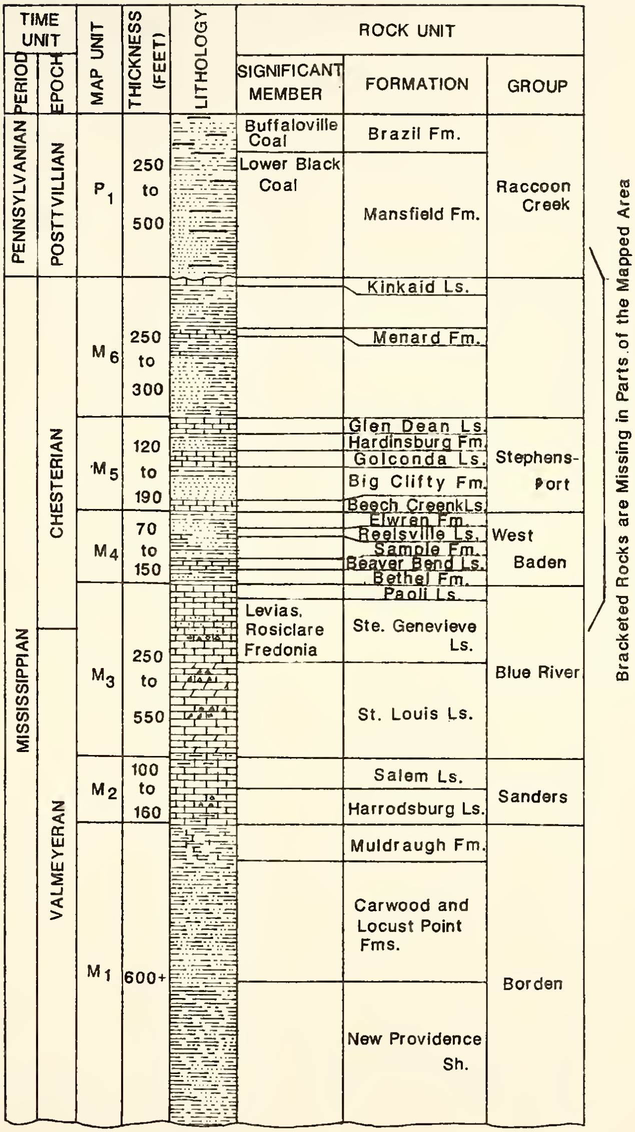

▧ Blue River Group Mostly fine-grained Limestone.
▤ Rocks of Late Chester Age Varicolored Shale, Sandstone and Limestone.
▨ West Baden Group Shale, Sandstone and Limestone, isolated deposits semiconsolidated sand
▨ Racoon Creek Group Shale, Sandstone, Siltstone, Limestone, Clay and (Coal*)
▧ Stephensport Group Limestone, Sandstone, and Shale.
* Coal is not mapped in Orange County.

Figure: 6. Bedrock Geology Map of Orange County.
(After Reference (2))



TIME UNIT		MAP UNIT	THICKNESS (FEET)	LITHOLOGY	ROCK UNIT		
PERIOD	EPOCH				SIGNIFICANT MEMBER	FORMATION	GROUP
PENNSYLVANIAN	POSTTVILLIAN	P_1	250 to 500		Buffaloville Coal	Brazil Fm.	Raccoon Creek
					Lower Black Coal	Mansfield Fm.	
MISSISSIPPIAN	CHESTERIAN	M_6	250 to 300			Kinkaid Ls.	
						Menard Fm.	
		M_5	120 to 190			Glen Dean Ls.	Stephensport
						Hardinsburg Fm.	
						Golconda Ls.	
						Big Clifty Fm.	
						Beech Creek Ls.	
		M_4	70 to 150			Elwren Fm.	West Baden
						Reelsville Ls.	
						Sample Fm.	
						Beaver Bend Ls.	
						Bethel Fm.	
		M_3	250 to 550			Paoli Ls.	Blue River
					Levias, Rosiclare Fredonia	Ste. Genevieve Ls.	
	VALMEYERAN					St. Louis Ls.	
		M_2	100 to 160			Salem Ls.	Sanders
						Harrodsburg Ls.	
		M_1	600+			Muldraugh Fm.	Borden
						Carwood and Locust Point Fms.	
						New Providence Sh.	

Bracketed Rocks are Missing in Parts of the Mapped Area

Figure: 7. Columnar Section of Bedrock Units in Orange County. (After Reference (2))

thin-bedded and highly jointed, resulting in the development of distinct karst topography along their outcrops. Chert is reported in abundant quantity (11) in the upper portion of the St. Louis Limestone. Karst development also is most pronounced in the St. Louis Formation. The Ste. Genevieve and Paoli limestones contain many sand-sized spheres of calcium carbonate called oolites. The Blue River Group limestone is the predominant lithology in the Mitchell plain. The upper members of the Blue River Group and the limestone members in the West Baden Group, also exhibit numerous sinkholes, and form low hills in the western half of the Mitchell plain (6).

The Crawford Upland which occupies a large part of the county (west, central and south), is comprised of a complex system of bedrock. Both the upper Mississippian and lower Pennsylvanian rocks are present (2). The Crawford Upland consist of interbedded layers of sandstone, siltstone, shale, and limestone. Rugged, blocky to angular topography results from extensive erosion of the weaker rocks. The oldest members are part of the West Baden Group and include the interbedded limestone, sandstone and shale of the Beaver Bend Limestone Formation, Bethel Formation, Elwren Formation, Reelsville Limestone, and the Sample Formation. The Stephensport Group includes the Beech Creek, Golconda, and Glen Dean Limestone Formations separated by the Big Clifty, and Hardinsburg Sandstone Formations (2). The limestones are characterized by solutioning which results in cavern and sinkhole development. The sandstone constitute the massive bluffs along many of the drainage divides.

Significant portions of the upper Mississippian rocks are eroded leaving only the rocks of the late Chester Age in the county. These rocks are comprised of varicolored shale, sandstone and limestone of the Menard Formation and Younger Formation (2). The rocks are overlain, unconformably by the Mansfield sandstone of the Raccoon Creek Group of Pennsylvanian Age. These Pennsylvanian rocks are massive, and highly jointed. Stratigraphic thickness of these rocks range from several feet (a few meters) up to 150 feet (45.7 m) or even more. See Figure 7 (2). In some places, the unit is composed of clay-shale and is much weaker.

Pleistocene Geology

Orange county is unglaciated, however, the Patoka and Lost Rivers and their major tributaries and creeks acted as major sluiceways carrying significant volume of meltwater during the Illinoian time; and probably include deposits of the Wisconsianan period of glaciation. The melting gave rise to the deposition of fairly large amounts of glacial debris along the course of these streams. These deposits are fine to medium textured. This is probably due to proximity of the county to the glacial melt front. The Patoka River valley contains up to 200 feet (60.0 m) of unconsolidated material as inferred from the bedrock topography map of Orange county shown in Figure 8 (10). Lost River contains up to 50 feet (15.2 m) of glacial sediments at the crossing

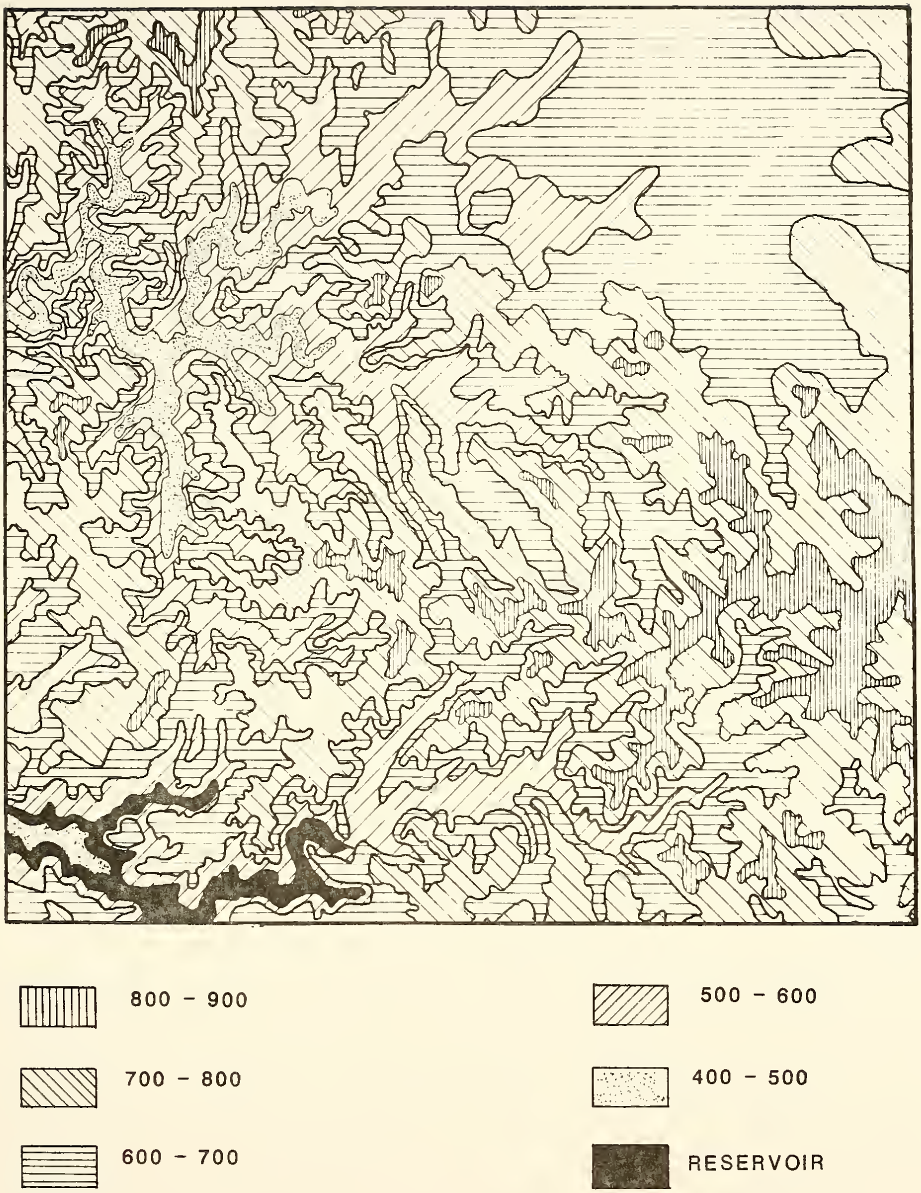


Figure: 8. Bedrock Topograpy Map of Orange County.

(After Reference (10))

of State Route 337 half way between Orleans and Bromer (2).

The unconsolidated deposits of Orange County are shown in Figure 9 (2). The Prospect Formation constitute the older alluvial deposits. This is composed mostly of alluvium, with some colluvial and lacustrine deposits of Illinoian Age. It occurs in isolated patches along the Patoka and Lost Rivers and their major tributaries. A few shallow lakes and/or slackwater plains resulting from blockage of sluiceways due to large amounts of debris during ice-melt, are present, but are not mapped as separate units. Fine textured deposits are common in these areas.

The younger unconsolidated material constitute the Martinsville Formation. This is comprised primarily of alluvial sediments but includes some colluvial and palludal deposits. These occur as silt, sand and gravel deposits along the Patoka River and Lost River.

Karst Topography

A pronounced karst topography is developed on much of the exposed limestone in the Mitchell Plain. This is characterized by numerous depressions, many caverns, subsurface openings, and a notable lack of surface drainage systems. These features are the consequences of the solutioning of the mineral calcite ($CaCo_3$), in waters in the presence of carbon dioxide, the major constituent of limestone. The chemistry of the reactions is summarized in the following chemical equations:

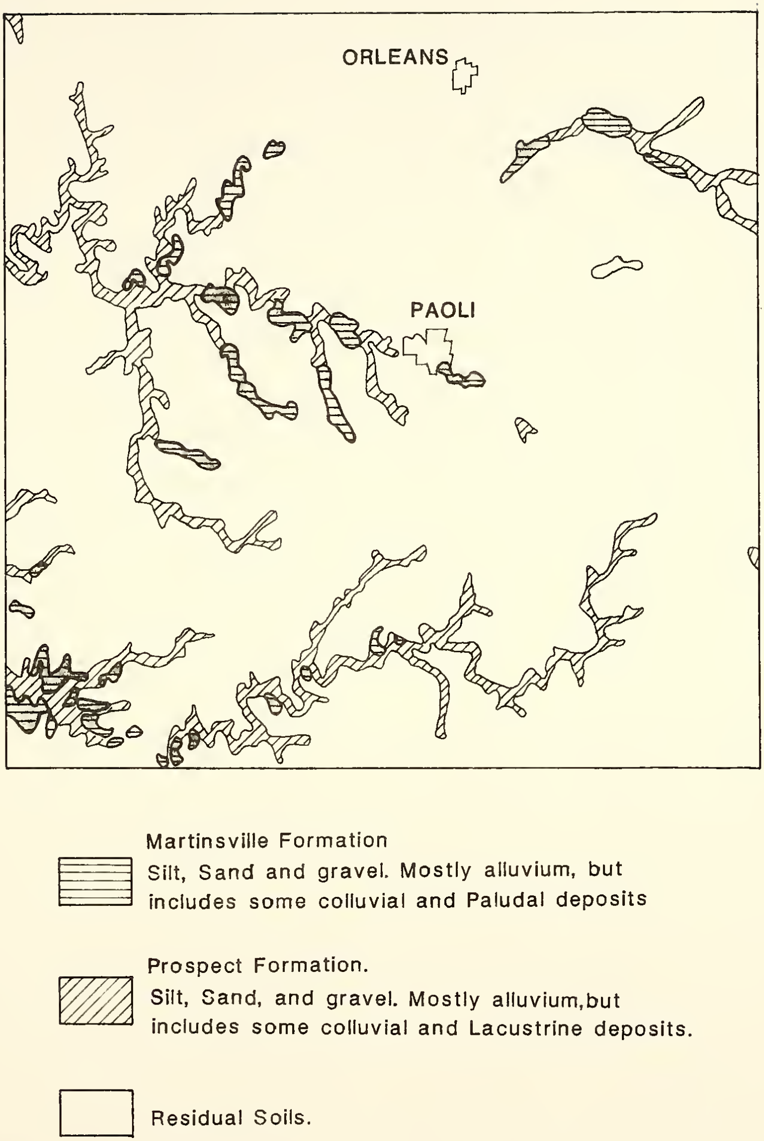

ORLEANS
PAOLI
▤ Martinsville Formation
Silt, Sand and gravel. Mostly alluvium, but includes some colluvial and Paludal deposits
▨ Prospect Formation.
Silt, Sand, and gravel. Mostly alluvium,but includes some colluvial and Lacustrine deposits.
☐ Residual Soils.

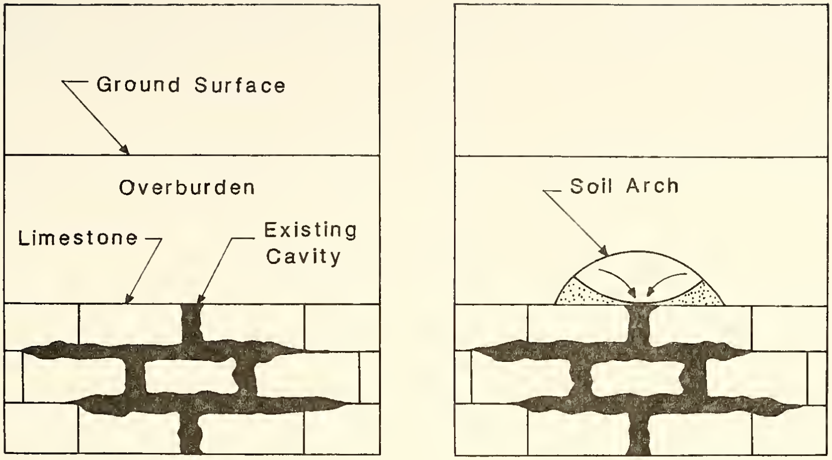
Figure: 9. Unconsolidated Deposits of Orange County.
(After Reference (2))

$$H_2O + CO_2 = H^+ + HCO_3^-$$
$$CaCO_3 + H_2CO_3 = Ca(HCO_3)_2$$

The carbonic acid (H_2CO_3), formed when carbon dioxide dissolves in water (H_2O), reacts with calcite to form calcium bicarbonate, Ca $(HCO_3)_2$, which is by far more soluble in water than the original calcite (11). The end product, calcium bicarbonate is then carried away by flowing water.

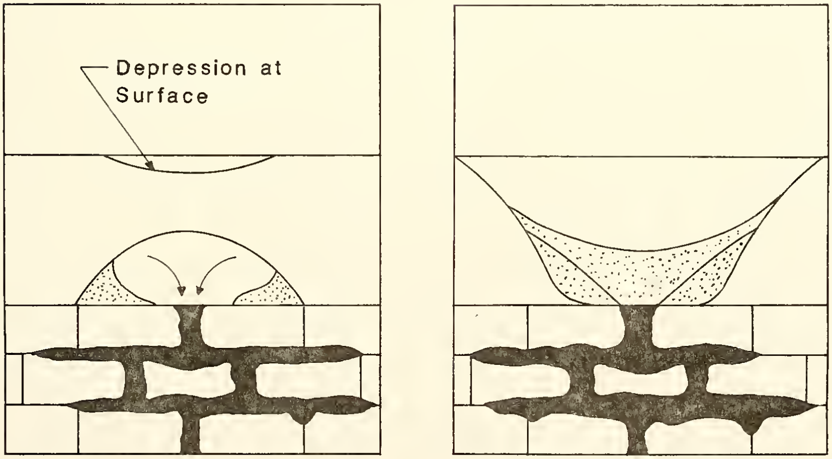
Sinkhole and karst development are attributed to four major conditions: (a) presence of soluble rock at or near the surface; (b) entrenched major valleys within the upland; (c) a dense, highly fractured, thinly-bedded rock; and (d) at least moderate amounts of rainfall (12). All of these conditions are satisfied in the Mitchell Plain area of Orange County. These conditions also are reported for the neighboring Lawrence County (11) to the north.

Figure 10, illustrates the process of sinkhole development (11). Large voids or caverns develop along joints and bedding planes where solutioning is initiated and largely concentrated. Following the increased cavity size and penetration of the overburden, an arch is created in the soil, followed by the development of a depression at the surface. The depression increases with time and in many places extends to a depth of 40 feet (12 m) or more. In many places, where parent bedrock is weathered, the soil bedrock contact is very irregular and large chert rock fragments are common in the soil profile. These abrupt changes from soil to rock are commonly seen along many road cuts in the



(a) Solution cavities exists, no downward movement of soil.

(b) Soil arch develops, soil migrate into cavity.



(c) Arch increases in size, subsidence evident at surface.

(d) Overburden migrates downward, dish-shaped depression at surface.

Figure: 10. Stages of Sinkhole Development (After Reference (11))

county. The varying nature of the soils and weathering of the bedrock, in addition to the development of caverns, present difficulties in design and construction. Therefore, careful study and engineering judgment are vital for development of engineered systems of karst areas.

LAND FORMS AND ENGINEERING SOIL AREAS

The engineering soils in Orange County are derived from geologically unconsolidated materials and from weathering of consolidated materials viz; sandstone, siltstone, shale, and limestone. The residual soils occur mostly on the uplands. Silty clay loams, silty clays, silt loams and clay loams are developed from the sandstones and shales of the Crawford Upland. Mostly silty clays and highly plastic clays are derived from the limestone bedrock of the Mitchell Plain. Thickness of the residuum is highly variable, especially in the limestone region. It ranges from bare rock exposure on some of the steepside slopes up to about 10 feet (3 m) of soil or more, on the flat uplands.

The unconsolidated materials include, fluvial and eolian deposits. Fluvial deposits are confined to the valleys and lowlands. Alluvial terraces and bedrock benches are common along the tributaries of the Lost River, Patoka River, and along some of the tributary creeks. Thin loess deposits occur over most of the county but are not shown on the map as a unique engineering soil area, however, it is identified by a textural symbol (see attached map). Lacustrine sediments are found in small terraces

along the Lost River flood plain near the entrance to the tributary valleys (2).

A general description of the engineering soil properties and characteristics are presented in this report, however, considerable variation is expected within any given land form and parent material association especially in the locations of transported materials.

General soil profiles showing textural characteristics expected for each engineering soil unit are presented on the map accompanying this report. Additional engineering properties and characteristics developed on representative pedalogical soil series for each land form type in addition to borehole data and engineering properties are given in Appendices A, B and C.

FLUVIAL DEPOSITED MATERIALS

Fluvial deposits in Orange county include soil deposits along flood plains and recent alluvial terraces, including reworked old terraces which are characterized by lacustrine deposits.

Alluvial Terraces

Alluvial terraces in Orange County are common along the toe-slope of the valley walls of major streams and creeks and their tributaries. They are mostly high, about 5 to 7 feet above the flood plains. These terraces are nearly level. The older terrace are much higher, they are also characterized by higher

silt content, are further from the flood plain, and are generally composed of moderately well-drained, silty-sandy soils. Infiltration basins are common, but current scars are rare, indicative of medium to fine textured soils which are generally well to moderately well drained internally.

The general soil profile of these deposits is variable, containing primarily sand, silt, clay, and some gravel, indicating the turbulent depositional environment of the streams (13). Fine textured layers of silt and clay are found throughout the alluvial terraces, but silt content is much higher in the older terrace. This indicates that the clay and silt layers are probably formed in slackwater-like environments in former topographic lows. The wide textural variation in this land form is shown on the general soil profile on the attached map.

The surface horizon of the well-drained, near-valley-wall soils is a clay loam to sandy loam (A-2), (A-2-4) with some gravel or a silt loam (A-4) which extends to a depth of 7 to 20 inches (50.8-177.8 cm) (3). Generally, the texture of the subsoil is variable with thin clay (2 to 4 inches or 5.1 to 10.2 cm) layers and pockets of coarse sand. The subsoil, in most places, is a sandy silt loam (A-4 to A-6) or silty sand (A-2) which ranges in depth from 20 to 70 inches (50.8-177.8 cm). The subsoil is underlain by stratified silts, sands and gravel (A-2) which extend to bedrock at a depth of 20 feet (6.1 m) or more.

The surface horizon of the finer-textured, moderately well-drained terrace soils is composed of silty clays (A-4 to A-6) or

silt loams (A-4) and is found to a depth of about 9 to 20 inches (22.9 to 50.8 cm) (3). These soils are mostly found near the flood plain in depressions and swales of the alluvial terrace. The subsoil similarly consists of clays (A-6 to A-7) and silty clays (A-6) which extend to a depth of about 20 to 80 inches (50.8 to 203 cm). The parent material of alluvial terraces are stratified sands and silts and are formed beneath the subsoil and extend to the bedrock. Textural variation occurs as the fine-textured deposits abruptly grade into the coarse-textured deposits.

Engineering problems associated with the coarse-textured, well-drained, alluvial terrace soils are not numerous (3). The parent material of these soils have high bearing strength (3,(3)). The soils are moderately permeable which is excessive where extensive pockets of coarse sand and gravel are located. The compressibility of the surface soils is generally moderate to high as reported "N" values (15) are usually under 10 blows per foot. The implication, therefore, is that loose surface soils and near-surface gravel pockets yield large initial settlements upon loading and, of course, intolerable differential settlements resulting from local variations in texture of the alluvial soils. The subsoils are generally non-plastic to slightly plastic (P.I. ranges from 5 to 15). Frost heave potential of the coarse-textured, well-drained soils is slight to moderate.

The finer textured, moderately, well-drained surface soils have moderate plasticity, with a plasticity index range of 5 to 20 and liquid limit of 25 to 40 (3). The near-surface and the subsurface soils are moderately compressible (3,14) and exhibit a low-bearing strength which increases with depth. Due to the amount of fines in the soil and a high seasonal ground water table, the frost heave potential is high in the finer-textured alluvial terrace.

Flood Plains

The soils developed on flood plains in the Mitchell Plain and Crawford Upland are not treated separately since there is no significant difference in the soil type and engineering behavior, except for the areal extent of the adjoining alluvial terraces which have been previously discussed. Areal distribution of the flood plain soils in Orange county are given in Table 2.

The flood plains consist of stratified alluvial sediment, generally well-drained, and are found along the Patoka, and Lost Rivers and their major tributaries and creeks, particularly Sulphur Creek, Log Creek, Willow Creek, Hogs Defeat Creek, Young Creek and Painter Creek. The flood plains range in width from nearly half a mile in some places on the two major rivers to a few hundred feet or less at points on some of the tributaries. Most of the narrow tributary flood plains (i.e less than half-a-mile), shown on the engineering map are not true flood plains, due to their steep gradient, however, they are so presented in

TABLE 2. AREAL DISTRIBUTION OF FLOOD PLAIN SOILS IN ORANGE COUNTY.

Pedological Series	Acres	Percent of County Area
Haymond	12,624	4.9
Wakeland	1,271	0.5
Wilburn	1,141	0.4
Burnside	2,996	1.2
	Total	7.0

order to show the location of these deeply eroded stream valleys or gulleys and to show their relationship with the true flood plains of the major rivers and streams. Nevertheless, alluvial sediments are found along these short tributaries.

The soils developed on flood plains are both well and poorly drained. The poorly drained soils are common in topographically low areas along major stream valleys in the western part of the county. Drainage conditions are improved in the east by the large number of sinkholes on the Mitchell Plain.

The flood plain deposits are nearly level, but broken only by former and present day stream channels. The land form include features such as channel markings, and old channel deposits. The features are mainly found in the valley of the major streams and their larger tributaries. Flooding is frequent in the topographically low areas, and is seasonally entensive along the lower courses of the major stream valleys.

Pedological soil series developed on flood plains in Orange County include the Haymond, Wakeland, Wilbur and Burnside series (3). Slopes are shallow (0 to 4 percent) along bottom lands. The soils are somewhat uniform throughout the profile and vary between loam (A-4) or silty clay (A-7) to a silt loam (A-4, A-6). Deposits of sandy loam occur in some sections (3) at depth of about 30 to 60 inches (76 to 152.4 cm.). Bedrock is as shallow as five feet (1.5 m) in the Burnside soils formed in the upper portions of stream valleys, but in general the bedrock occurs at

much greater depth. The flood plain alluvial soils are derived from the residuum and loess of the surrounding uplands and are, therefore, usually finer-grained than other soil types.

Borings numbered 5, 8 and 12 are located along S.R. 37 near the flood plain of Hogs Defeat Creek in Sections 6 and 31 of T1S,R1E. The boring data (16) reveals a weathered shale bedrock at a depth of 6 to 15 feet (1.8 to 3.0 m) or more along the outer portions of the valley away from the stream channel. The soil is predominantly a silty clay (A-7) with shale fragments. The deposit increases in thickness toward the center where the surface soil changes to a silty clay loam (A-4, A-6, A-7). A subsoil of dense sandy loam (A-2) with gravel is encountered at a depth of 5 to 12 feet (1.5 to 3.6 m).

Borings numbered 13, 20 and 21 are located along S.R. 145 in the stream valley and along the flood plain of the Patoka River and Painter Creek in Sections 10, 11, 14 and 15 T1S,R2W (17). The representative subsurface profile consists of a loam, or sandy loam (A-2) with some weathered sandstone and/or some traces of gravel in the lower horizon. Sandstone bedrock is at a depth of 12 to 22 feet (3.6 to 6.7 m) with limestone at about 25 to 30 feet.

The soils of this unit are generally unsuited to building sites because of their low shear strength, high compressibility, as well as high potential for flooding. Bedrock is not deep along the small stream tributaries; thus, in such places bridge

design and construction are not too difficult. Along the major rivers where bedrock occurs at greater depths (more than 30 feet 9.0 m) and where thickness of the alluvial sediments is greater, bridge design and construction definitely requires considerable field study. Development in the flood plains is restricted to cultivation and recreation.

RESIDUAL MATERIALS

About 70 percent of Orange County is covered by residual soils developed over limestone, siltstone, sandstone, and shale benches, plains, and plateaus. Soils of limestone origin are found throughout the Mitchell Plain and extend into the karst controlled benches of the Crawford Upland. Shaly and sandy residuum develop over the hills and ridges of the Crawford Upland. The topography of these areas is characterized by moderate to steep slopes and level upland areas. The landform and the parent material type in this area are discussed separately in the following sections.

Sandstone-Shale and Siltstone-Shale Over Limestone Plateaus and Benches

About 40 percent of Orange County is occupied by residual soils derived from interbedded sandstone-shale plateaus. The variability and complexity of the subsurface profiles are such that the unit is divided into three parts: soils associated with interbedded sandstone shale-limestone parent bedrock in plateaus, those on the sandstone-shale plateaus; and those formed on the

steeper sideslopes of the dissected plateus. Soil texture, depth to bedrock and erosion characteristics are different for the three groups.

(a) Sandstone-Shale Over Limestone Plateaus

The soil cover in this unit is different from the residual soil cover found where parent material is predominantly sandstone-shale. The sandstone-shale over limestone residuum is at a depth of 4 to 20 feet (1.2 to 6.0m), with the shallower soils located on the ridge tops and upper sideslopes and the deeper soils found on the lower sideslopes. Rock fragments are encountered throughout the soil profile. Groundwater is noted at a depth 5.9 feet (1.71m), in boring 24, 26; and at 4.0 feet (1.2 m) in boring 27 (16).

Borings 14 through 19, are located along SR 145 further away from the Painter Creek flood plain in the western part of the county (17). The soils are predominantly silty clays (A-6, A-7-6) and clays (A-7-6), and Silty Clay loam (A-4, A-6). This location is typical of this part of the Crawford Upland. The soil consists mostly of silty clay (A-6) and silty clay loam (A-4, A-6 in the upper horizon, about 1 to 3 feet (0.3 to 0.9m) deep, and is underlain by stiff brown clay with fragments of highly weathered shale with traces of sandstone, about 3 to 5 feet (0.9 to 1.5 m) deep. The lower portion is composed of either a shale, a sandstone or a limestone bedrock.

Many engineering problems are encountered in the interbedded sandstone, shale, and limestone areas. The complex geology, its

rugged topography and variable depth to bedrock pose serious problems in planning cut and fill requirements for highways. Due to the varying parent material types and their soil associations, slope instability is common along highway cuts. The shaly soils constitute a unique problem when needed as fill in an embankment. Problems of slaking of the shale and difficulty in compaction arise when they are used as fill in an embankment (11, 19). These problems require that special procedures be used when shale is used as a construction material. Solution features, commonly sinkholes, develop where limestone is close to or at the surface. The clayey soils are generally poorly drained and as such cause drainage problems in this area. Due to the rugged nature of the area, development is restricted to the ridge tops and perhaps broader drainage divides.

(b) Sandstone-Shale Plateaus

The residual soil thickness in the sandstone-shale plateaus is greater in depth than the adjoining more steeply sloping areas. The soils are derived from clastic parent rock and are common on the ridges and flat uplands of the highly dissected sandstone-shale plateau. A moderately thin blanket of loess (in the Crawford upland, occupying the northwest and southwest part of the county) covers the residuum throughout this unit (2,20). The agricultural soils formed in these areas include the Ebal, Gilpin and the Wellston series. Ebal soil is formed on the flatter portions of the plateau, with slopes ranging from 0 to 18

percent. The residuum is 4 feet (1.2m) or more in thickness (3). A topsoil silty clay loam (A-4, A-6) 0 to 9 inches (0 to 22.5 cm) thick, overlies 9 to 19 inches (22.5 to 47.5 cm) of silty clay (A-7). The substratum is composed of either clay (A-7) or silt loam fragipan that extends to bedrock. In general, the Gilpin soils are composed of silt loam to very shaly silty-clay loam containing upto 30 percent rock fragments greater than 3 inches (7.6 cm) in size, and are classified as A-1, A-2, A-4 or A-6. Wellston soils composed of about 35 inches (88.9 cm) of silt loam (A-4) or silty-clay loam (A-4, A-6, A-7), underlain by shaly to very shaly loam to a depth of 72 inches (182.9 cm) where bedrock is encountered (3).

The upland residual soils are moderately plastic. Ebal soils have plasticity index of 5 to 20, with a liquid limit range of about 25 to 45. Gilpin soil plasticity index ranges from 4 to 15 with a liquid limit range of 20 to 40 and the Wellston soils plasticity index is 3 to 20 with a liquid limit range of 25 to 40 (3). In general, the soils are fairly impermeable yielding subsequently low infiltration rates and high runoff coefficients. The upland residual soils are of moderate to low bearing capacity (3,11,14) and are moderately compressible. Sound bedrock occurs at depths less than 7 feet (2.1 m) and have an RQD* value over 70 (3, 17) (See Appendix A). Frost heave potential is high to

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* RQD (Rock Quality designation) Goodman (1980 (15) defines RQD of a Rock as the percentage recovery of core in lengths greater than twice its diameter. A diameter of 2.125 inches is usually adopted (NX Core), thus allowing for rejection "from the recovered category fragments less than 4 inches in length"

moderate and is greatest where the loess blanket is thickest. Pumping is common in compacted fills for roadways. Piping is a problem in places where silty soils are used for constructing farm or residential water retaining embankments.

c). Sandstone-Shale Plateau Sideslopes

Soils developed over sandstone-shale sideslopes are common on the steep-sloping hills of the Crawford Upland in the northwestern and southwestern portion of the county and are also encountered in the south central portion. Generally, the soils on this landform are shallow and contain more rock fragments than those of the adjacent upland surfaces.

The predominant agricultural soils include the Gilpin and the Wellston Series, formed on slopes up to 50 percent. Large fragments of shale, siltstone, and sandstone are common. In areas where residuum is developed, the upper horizon consists of 10 to 15 inches (25 to 38.1 cm) of silt loam (A-4) or channery (stony) silt loam (A-2, A-4). The subsoil consists of very channery silt loam interspersed with loam (A-2, A-4). Rock fragments greater than three inches (7.62 cm) in size comprise up to 35 percent of the soil. Bedrock is at a depth of 20 to 35 inches (50.8 to 88.9 cm).

The engineering properties are similar to those described for the cohesive soils found in level upland soils. The soil is moderately plastic with moderate shear strength (3, 14, 18). Problems encountered here are similar to those listed for the low

level upland soils. Additional engineering problems encountered are high surface runoff and consequent erosion and slope instabilities. The 1971 slide on US-150, three miles west of Prospect, was caused by drainage in addition to other slope related factors (21).

d) Benches in Sandstone-Shale Plateau

Benches composed of mainly limestone interlayered with sandstone in the sandstone-shale plateau are present along the valley walls of the major stream and creeks in the western part of the county. Rock benches are common along Lost River, French Lick Creek, and their larger tributaries. They are located 15 to 40 feet above the flood plains and are fairly flat.

The predominant agricultural soils include the Caneyville, Crider, Gilpin and Wellston series. These are developed on thin veneer of loess overlying soils developed from the underlying bedrock.

The residual soils formed over bedrock benches in the sandstone-shale plateau, are generally cohesive and moderately well drained. Liquid limits for the subsoils range from 25 to 65 with plasticity index of 4-40 (3). The surface soil is silty and is less plastic. The soils generally have low bearing strength. Pumping, frost heave potential, and piping is high as a result of high silt content. Generally residual soils developed on the rock bench are poorly drained internally, and, hence, the high surface energy and erosion from these soils. Water table in these soils is seasonably quite high.

Limestone Plains and Benches

Residual soils of limestone origin, cover about 30 to 40 percent of the county. They are developed on the broad limestone plain of the Mitchell Plain physiographic subsection, but are also found along the Karst valleys and on benches adjacent to stream valleys in the Crawford Upland. Karst topography is a characteristic feature of this unit especially in the northwestern, north central and southern portions of the County. Solution features such as caverns, sinkholes, and subterranean cutoff, and subterranean drainage (Lost River) are very common.

Sinkhole development is intensive especially around Orleans and in the vicinity where the Lost River disappears underground. The density of sinkholes ranges from less than 30 to as high as 500 per square mile (2.50 square kilometer). Similar range of sinkhole distribution density is reported for the neighboring Lawrence County (11). Sinkhole development is higher in the northeastern quarter of the county, where the bedrock is entirely limestone, than in the western part where bedrock comprises layers of sandstone, shale, and limestone. The limestone is in the lower part of the section and occurs as outcrops on sideslopes and in benches.

The predominant textures of the limestone residual soils are silty clay loam and silty clay. Because of the differences in textures, depth, and thickness, the soils developed on limestone

residuum are discussed in three categories: a) limestone plains, b) limestone sideslopes and c) limestone benches.

a) Limestone Plains.

The limestone uplands of the Michell Plain, characterized by rolling to gently sloping surface, have moderately deep residual soils developed on them. The soils are developed on a thin veneer of loess less than two feet (0.61m) thick. The unit is therefore silty in its upper horizon and is moderately well-drained. Surface streams are generally not well developed. Swallow-hole type drainage is common. Areas characterized by steep slopes are highly dissected. The Lost River in the north central part of the county, has cut deeply into the Michell plain, producing narrow, steep sided, gorge-like valleys, which become broader and wider in the northeastern part of the county where the slopes are gentle. Thick residuum is common on the broad drainage divide between the deep, narrow valley and on the divide between sinkholes.

The Bromer, Bedford, Crider and Frederick series are the predominant agricultural soils found on the uplands. Crider, and Bedford soils develop on the rolling uplands and are about 70 to 80 inches (175 to 200 cm) thick, and are more clayey in the lower horizon. They are formed on slopes of 0 to 30 percent. The Bromer soils are developed in upland depressions, and are somewhat poorly drained, and slowly permeable. They are formed on a slope range of 0 to 2 percent. Fredrick soils are found in lower por-

tions of sinkholes, and on the steeper slopes (2 to 50 percent) (3).

The generalized profile is composed of 10 to 50 inches (25 to 127 cm) of silt loam (A-4, A-6), underlain by 6 to 20 inches (15 to 50 cm) of either clay loam (A-6, A-7) or silty-clay loam (A-4, A-6, A-7). This zone extends to a depth of 70 inches (178 cm). The third zone is predominantly composed of clay or cherty clay (A-7). Limestone bedrock is encountered at a depth of 75 to 85 inches (190 to 215 cm) or more.

b. Limestone Sideslopes:

Variable depth to bedrock and thinner mantle are some of the characteristic features of residual soils developed on limestone sideslopes. The unit is also affected by intense gulley erosion. The agricultural soil series found on the limestone sideslope, include the Caneyville and Fredrick soils. They are developed on slopes of 2 to 70 percent. The upper horizon is composed of 4 to 19 inches (10 to 48.3 cm) of silt loam (A-4, A-6) underlain by a 13 inch (32.5 cm) layer of silty clay (A-7), and this is underlain by a zone of clay (A-7). Depth to bedrock ranges from 18 to 80 inches (45 to 203 cm). Bedrock depths are generally shallow. Thin soils occur on the upperpart of the sideslopes and deeper soils on the lower part of the sideshope.

c. Limestone Benches:

Limestone benches occur throughout the county, but cover greater areas in the eastern part of the county (see attached

map). As in the case of the benches in the sandstone-shale plateau area, the benches in the limestone areas, occur adjacent to the karstic valleys, and flood plains. They appear as nearly flat to pitted surfaces, separated by a topographic rise above the flood plains. The Caneyville and the Crider Series are the major agricultural soils that develop on this land form. Sinkhole development is common on the limestone bedrock benches. The upper horizon is comprised of mostly silt loam (A-4, A-6), or silty clay loam (A-6, A-7). The lower horizon is generally more clayey especially around the areas dotted by sinkholes.

The generalized soil profile is composed of 9 to 20 inches (22.8 to 50.8 cm) of silty clay (A-4, A-6), underlain by 12 to 18 inches (30.5 to 45.7 cm) or more of either loam (A-6, A-7) or silty-/clay loam (A-4, A-6, A-7). The third zone is composed of varying amounts of clay (A-7) and/or silty clay (A-60) and weathered limestone fragments. Limestone bedrock is encountered at a depth of 35 to 60 inches (88 to 150 cm) or more. Occasional sandy loam or sand is sandwiched between the third zone of clay (A-7) and the bedrock, especially close to the tributaries of major streams and creeks.

Boreholes 30 through 35 are located along a new relocation area for the existing bridge for U.S. 150 over No Name Creek, about half a mile northwest of Paoli, the county seat. This structure is located in an area of limestone bench adjacent to sandstone-shale sideslope soils. The residuum over the limestone

bedrock bench consists of an upper layer of silty clay, or silty clay loam (A-4, A-6), underlain by loam, or silty loam (A-6). The third zone is composed mostly of silty clay or clay (A-6, A-7). The bedrock is limestone and occurs at a depth of 8 to 9 feet (2.4 to 2.7m) (22). RQD (Rock quality designation, - See page 34 for definition) range from 90 to 96 (See Appendix A4). In boreholes 31 and 32 sand and gravel are encountered at a shallow depth. These boreholes are located near the No Name Creek river bank.

The limestone areas exhibit several engineering problems. Solutioning of limestone is a major problem and this leads to the creation of subsurface cavities and sinkholes. Cavities and sinkholes constitute a major threat to construction of highway embankments or foundations. This, therefore, requires a careful and continuous plan of repairing sinkholes to minimize the potential of future collapse. Also, alteration of surface drainage is to be minimized as this affects the subterranean drainage and, hence, the sinkholes in the area. Deep foundations or large excavations need to be carefully planned as weathering of the limestone bedrock is highly irregular. Generally, great difficulty exists when planning cut and fill operations for highways in the limestone area.

Reworking of the highly plastic clay in the limestone area, generally destroys the clay fabric and causes a decrease in permeability among other things. In its natural state, the permeability of the residual clayey soils is high due to its high

internal drainage due to a well developed blocky soil structure. Also, these soils have a high potential for pumping and as such are considered a poor subgrade material. Development on the limestone is possible, if a careful study is made concerning the engineering behavior of the soil and rock particularity in the sinkhole areas.

MISCELLANEOUS

Quarries:

Several quarries are located within Orange County. Most of these are located in the limestone plains and along the boundaries of the Mitchell plain and Crawford Upland, where both the Mississippian, and Pennsylvannian limestones outcrop and are mined. The limestone in Orange County is generally surface mined, and is as much as 60 feet (18.3m) or more deep in some places. Cave Quarry, about three miles northwest of Paoli, is a typical example. The quarry is about a quarter-square mile (0.32 sq.km) in area, and with over 50 feet (15.2m) of surface mined limestone, The limestone quarries produce mainly limestone aggregate and agricultural lime. Sandstone quarries no longer exist in Orange County. In the past, sandstone was also quarried for use as building stone from the sandstone-shale plateau area.

ENGINEERING PROBLEMS

General

The engineering problems related to the soils and rocks of Orange County are discussed in a greater detail in the following section. This is included to present the engineer involved with design and construction, and the construction supervisor with an idea of the potential field problems. The potential problems are divided into the following categories.

1. Construction Material
2. Excavation and Foundation Problems
3. Slope Failure
4. Waste Disposal System
5. Seismicity
6. Shale Embankments
7. Summary

Construction Material

Orange county does not have abundant deposits of sand and gravel, and because of the abundance of fines (silts and clay) in these deposits, they are generally not cost effective, as thorough processing of these materials is required before usage.

Crushed stone from limestone quarries constitute the major source of aggregate supply in Orange County. These are used as building stones, sub-base materials for highways, as ballast for railroads and in some cases as agricultural lime. The Cave and

Calcar quarries located west and east of Paoli, respectively, are the major sources of crushed stone in Orange County.

The alluvial terrace materials in Orange County generaly do not meet general AASHTO grading requirements (Designation M147) for subbase and base course, and as such are not in frequent use as sub-base materials, because of the high potential for frost heave.

Most of the soils of Orange County are acidic. The pH ranges from 3.6 to 5.5 for the moderately well drained soils of the bedrock, terrace, and flood plain areas. Corrosion of metal pipes and concrete structures in these areas is caused by the acidic nature of the soils.

Concrete corrosion is most severe in places where poor quality concrete is used to build structures (e.g. footing for light poles, walkways, etc). Due to constant flooding conditions, corrosion is more intense on structures built in the flood plain areas.

Steel pipe corrosion in Orange County is a serious problem affecting almost all the areas in the county. This is attributed to the highly acidic nature of the soils particularly the residual soils with pH ranges between 3.6 to 5.5. Reduction in life span of metal pipes from 40 to 15 years are reported in nearby Brown County (14), where soils with similar acidic conditions are present. Aluminum pipes are used in nearby Barthorlomew County to minimize corrosion (23). Corrosion protection evaluation is needed for each specific pipe location.

Excavation and Foundation Problems

Serious excavation problems are common in the limestone areas especially when large excavations or deep foundations are planned. This is due to the irregular weathering of the bedrock surface. This is worsened by solutioning of the limestone bedrock, which generally creates subsurface cavities. This condition requires extensive repair of sinkholes to minimize collapse when a structure is founded on these soils and/or their parent material. Because of the extensive cavitation in this area, deep foundations are recommended for all moderate to large structures. In areas where houses and other structures rest on shallow foundation, cracks as much as four inches wide are observed in some cases. These are caused by differential settlement of the structures following solutioning of the subsurface bedrock, cavitation and collapse of the bedrock.

Soils and parent materials in the sandstone-shale area (western part of the county) provide adequate foundation support for light to moderately loaded structures, particularly in areas where sinkhole or subsurface cavities are absent. In Paoli, where most of the heavy buildings in Orange county exist; foundation performance is moderate like in Brown and Bartholomew Counties (14,23). Most of the houses are founded on the bedrock, and in some cases on the residual soils developed from the sandstone-shale over limestone bedrocks. Significant problems

arise where the water table is high, as this causes slaking of shale bedrock. Many houses are built on the flood plains of the French Lick Creek in the towns of West Baden Springs and French Lick. Mat foundation are used for most of these structures.

Excavation problems are common in the flood plains and alluvial terraces. A dewatering plan is required in this area, due to high permeability of the soil and relatively high water table [2 to 10 feet (13)]. Typically the sideslopes are not always braced, as most of the slopes are cut at an angle of repose. However, where excavations are adjacent to highways or major buildings, bracings are recommended.

Foundations for bridges, are of major concern in Orange County, particularly where the highway is routed through the limestone country. This is due to the numerous caverns and sinkholes in the area. Most of the bridge foundations are either H-piles, steel shell friction piles or steel encased concrete piles (18). The major problem in the limestone plain, is the collapse of pre-existing sinkholes in the vicinity of a bridge. A similar problem exists in the south-central part of the county, where sandstone and shale is interbedded with limestone. A typical bore hole record taken from the location where S.R.37 crosses the Patoka River is shown in Appendix C. The soil profile consists of layers of loose to very loose clay loam, three to five feet thick. This is underlain by a loose sandy loam layer with some sandstone fragments. The third layer comprises bluish-gray argillaeous limestone, averaging five feet thick (24). Due to

the variable nature of these deposits, and due to extensive sinkhole development, a careful subsurface exploration program is recommended for any project in the county. In view of these problems, extensive seepage control measures were adopted for the Patoka Dam. Details of these measures are documented by reference (25).

Slope Failure

A few slope failures are reported in Orange county. These are mostly man induced. A significant slope failure occurred on U.S. 150, approximately three miles west of Prospect investigated by the Indiana Department of Highways, Materials and Tests Division (21). The cause of the failure is not conclusively determined but there is a strong belief that lack of provision of drainage facilities and adequate specifications for selection of embankment materials are largely responsible for the failure. This portion of the highway was constructed in the early 30´s when adequate testing procedures for determining degradation of embankment materials were lacking. Other ways by which slope instability occurs include: a) saturation of slope, b) overloading the head of the slope, c) oversteepening by a cut, and d) removal of toe support.

Alluvial terraces are susceptible to circular type slope failures. Although these terraces offer good flood protection to structures built there, slope failure occurs following alteration of the natural slope by construction and increased runnoff.

Failures in these slopes usually are in the form of slumps, or as well defined failure scarps with distinct slopes as high as two feet or more. These slopes require, therefore, minimal construction alteration, and significant effort to control runoff. Where lacustrine deposits are present, the natural slope angles are not to be used as guides for design. This is because dissipation of induced porewater pressures in these materials is extremely slow; thus, requiring the use of undrained-strength parameters in analysis, as opposed to drained-strength parameters that is required for other types of natural slopes.

Both the sandstone-shale soils and the limestone soils have moderate to high potential for slope instability. Because of seepage due to layering and differential weathering of the sandstone-shale units, there is a potential for slope instability in these landforms. The soils are generally 0 to 9 feet thick and are susceptible to sliding along the planar rock interface. Similar soils in Brown County are reported to be quite unstable at slopes of 30-45 degrees (14). Typically, the slope is initially weakened by removal of the toe (maintenance error or by construction activity), and then the slope fails upon saturation after heavy rainfall. Based on simple planar analysis, and field observations, it is found (see reference 14) that for a slope of 45 degrees, with unconfined compression strength ranging from 250-500 psi, that the minimum critical soil depth ranged from 4 to 7 feet. In general, factor of safety decreased with increasing depth of residual soil.

Rock slope instabilities such as wedge failures, are not common in Orange County. This is largely due to the nearly horizontal bedding and insignificant dip (one foot per mile) of the rocks, and the wide spacing of the joints (3 to 15 feet). However, in the Sandstone/Shale/Limestone Plateau, differential weathering causes instability. The unweathered rock mass quality is termed "good" by the Congress of the Society for International Rock Mechanics, (CIRS), rock mass rating system (27). The rating system relates joint spacing and orientation, rock type, and rock orientation to construction problems in rock. Because of solutioning and subsurface cavities in the limestone bedrock, this rating is not applicable in the eastern part of the country where limestone constitutes the major bedrock type.

Waste Disposal Systems

There are many unsuitable areas for disposal of wastes and for the location of septic-type sanitary facilities. These include, (1) the flood plains, which are highly susceptible to flooding, (2) the terraces, which are gravel acquifers, and (3) the bedrock benches (limestone bench and shale/sandstone bench), which are limited by the shallow depth to bedrock and possible sinkhole development. Upland surfaces with deep soils underlain by massive shale units are possible sites with minimum environmental problems.

Seismicity

Seismic stability is considered a major aspect of all stability evaluation for engineered structures, particularly dams, to minimize loss of human life and damage of property. Figure 11, (28), is a generalized map showing the different seismic zones of Indiana, with respect to expected earthquake intensity (zone 3 being the most intense). Information concerning minimum requirements for seismic design of dams are given in Table 3 (28). Other requirements to consider in aspects of dam stability evaluation are piping, slope stability, and seepage.

Major earthquake events, such as the New Madrid earthquake of 1811 which impacted this county, may produce devastating affects that render all design precautions ineffective; nevertheless, the importance of these precautions need not be overemphasised as they offer reasonable protection against serious damage in lesser events.

Shale Embankments

In the early 1930´s, state road and major county road embankments were constructed out of shales, particularly in the sandstone and shale plateau. These embankment materials were not tested as the standards require today. Problems occur as these shales weather into a soil-like material. Voids in the once hard material subsequently collapse causing very large settlements and embankment slope failure.

A grading system of the shales has been devised to predict and optimize performance of these shales used as fill materials

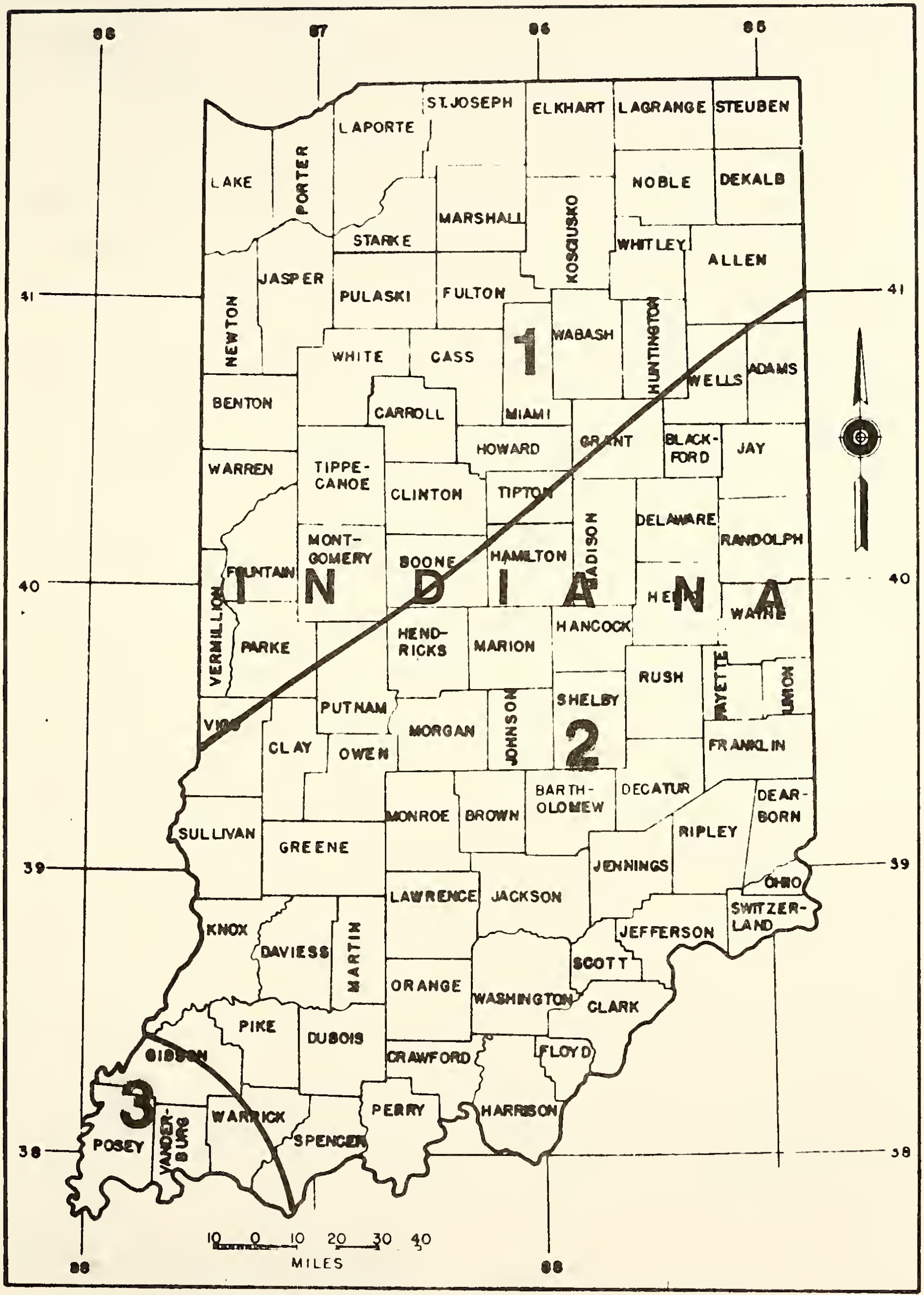

Figure: 11. Seismic Zone Map for Indiana

(after Reference (28))

TABLE 3. MINIMUM DESIGN REQUIREMENTS FOR SEISMIC ZONE 2 AREA OF INDIANA. (28)

HAZARD CLASS A --- Potential for Agricultural Damage

1. The fill will have a coarse grain downstream shell,
 or
 A self-healing GC or GM core
 or
 A downstream coarse grained transition section $0.25H <$ width $> 15'$
 or
 The minimum top width $= 1.25 (H + 35) / 5$
 and

2. Slopes will be designed for factor of safety = 1.0 with a seismic coefficient = 0.10 g

---

HAZARD CLASS B --- Potential for Property Damage

1. The fill will have a coarse grain downstream shell,
 or
 A self-healing GC or GM core
 or
 A downstream coarse grained transition section. $0.25H <$ width $> 15'$
 or
 The minimum top width $= 1.25 (H + 35) / 5$
 and

2. Slopes will be designed with a factor of safety = 1.1 with a seismic coefficient = .10 g
3. Additional freeboard = $.05H$ will be provided.

HAZARD CLASS C --- Potential for Loss of Life

1. The fill will have a coarse grain downstream shell,
 or
 A self-healing GC or GM core
 or
 A downstream coarse grained transition section. $0.25H <$ width $> 20'$
 and

2. The minimum top width $= 1.25 (H + 35) / 5$
3. Slopes will be designed for a factor of safety = 1.1 with a seismic coefficient = .10 g
4. Foundation materials with a sensitivity > 4 will be removed or proven adequate.
5. Sand foundation materials with relative density < 70% will be removed, consolidated or proven adequate.
6. Additional freeboard = $.05H$ will be provided

(29). The system consists of several tests and the results are used to rate the shale. Correlation charts which compares this rating with construction practice and soil parameters are used for design.

One of these tests is called the slake durability test. This test simulates long term degradation due to weathering of the shale. The test procedure involves the introduction of five, ten-gram shale pieces in a rotating drum half submerged in a water sink. After 200 revolutions the shale pieces are taken out, oven dried, and then put through another 200 revolution cycle. The remaining shale pieces are then weighed and the shake durability index is computed as follows:

$$I\ (d) = \frac{\text{Weight after 2nd cycle}}{\text{Weight before 1st Cycle}} \times 100$$

Shales with I(d) less than 80 are classified as soil-like and normally act like soil if allowed to weather. The shales in the sandstone-shale upland of Orange County are classified as soil-like (Table 4).

The Franklin rating chart, (devised for classification of shales in terms of durability), Figure 12, (29), combines the slake durability test with the plasticity index (for I(d) > 80, a point load test is used instead of plasticity index to produce a rating). The ´R´ ratings for the Borden Group shales (New Providence and Locust Formations) are given in Table 4.

Several compaction degradation tests have been run on these shales (19, 30). The results indicate that they are extremely

Index of Crushing and Coefficient of Variation for Impact Compaction Samples (29).

Shale	Effort Level $\frac{kN - m}{m^3}$	Index of Crushing: Mean Value (%)	Index of Crushing: Coefficient of Variation (%)
New Providence	1) 527	25.7	10.4
	2) 790	37.6	5.6
	3) 1451	43.9	5.0
	4) 2414	57.7	3.9

Average Properties of Compacted Shales (29).

Rock Name	S.D.%	L.L.	P.I.	Estimated Franklin Rating R#	Max. Dry Density (PCF)	Optimum Moisture (%)	CBR 95% of Optimum	Rocklike or Soillike
ew Providence Shale	69-71	27-34	5-10	4.2	119-121	10-13	8-11	soil
ocust Point Formn. (upper)	67.6 (26.9)A	27-28	8	53.8	119-122	11-13	8-11	soil
(lower)	73 (42.6)A	27.2	8-9	54.2	123-127	10-11	10	soil

A - Based upon 500 revelations. The recommended laboratory (Oakland, 1982) procedure suggested that the shale durability index be computed after 2-200 revolution cycles. It has been found that beyond this recommended limit, the constant between soil-like soft shales is reduced.

B - Based upon a single cycle of 200 revolutions.

TABLE 4. THE 'R' RATINGS AND PROPERTIES OF SOME COMPACTED SHALES.

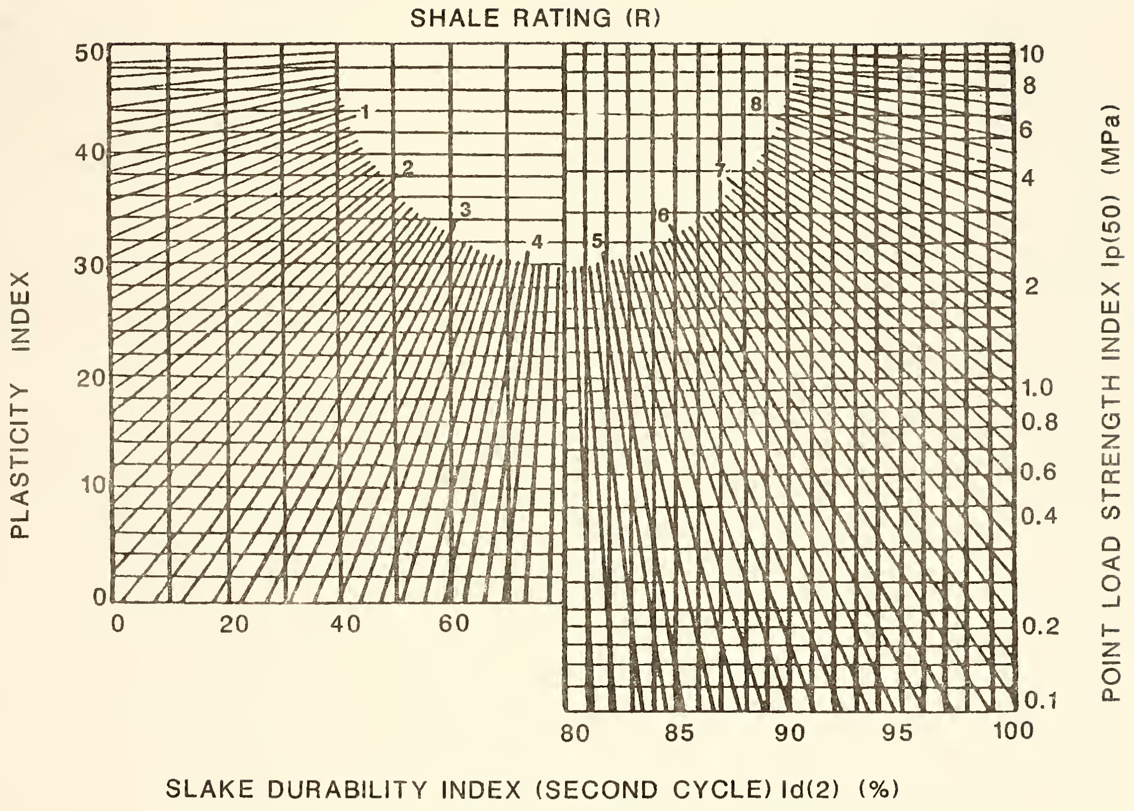

Figure: 12. Shale Rating Chart (After Reference (29))

difficult to break down inspite of their longterm behavior as soil-like materials. This strange condition requires the use of strict compaction control during construction. Figure 13a taken from (29), shows the minimum lift thickness and compaction densities as a function of ´R´. Figure 13b (29) shows the correlation between the ´R´ rating and drained shear strength parameters.

Sandstone and siltstone layers are common within the Borden Group rocks. These may constitute a problem when used in conjunction with the shale as fill material, as they may not break down. This may give rise to poor performance as drainage and infiltration become highly uncontrolled. This problem can be minimized by providing adequate drainage, encasing the clay layers and using adequate vegetative cover to minimize infiltration.

Summary

A summary of the geotechnical problems of Orange County is presented in Table 5. Each parent-material type or soil type is rated qualitatively for its probability of major problems occurring for a number of engineering activities. The ratings reflect what is considered to be the average character of the soils.

This report highlights and warns of the potential problems associated with the geologic parent materials of the County. The report and the map are important tools for planning site investigations, and, therefore, are not to be used as a design tool.

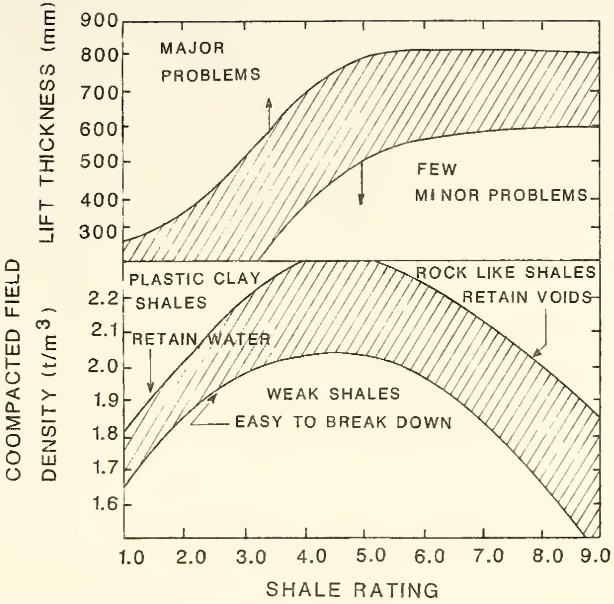

Figure: 13a Tentative Correlations Between Shale Quality, Lift Thickness and Compacted Densities (After Reference 29)

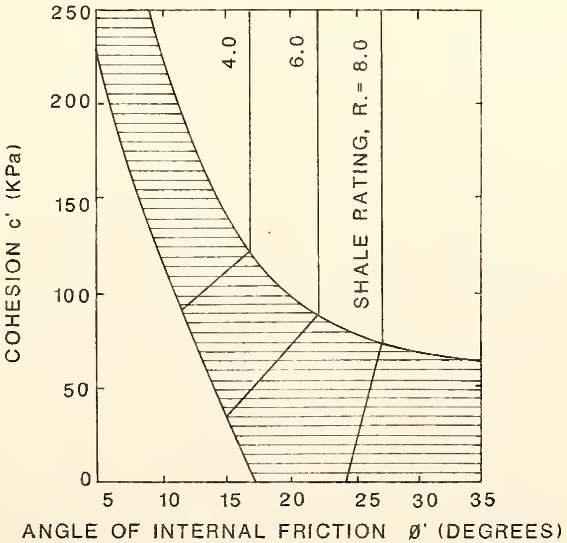

Figure: 13b Trends in Shear Strength Parameters of Compacted Shale Fills as a Function of the Shale Quality (After Reference 29)

TABLE 5. RATING OF HIGHWAY SOIL CONSIDERATIONS FOR ENGINEERING SOIL MAP UNITS OF ORANGE COUNTY

Symbol Explanation

Probability of Major Problem Development

L - Low
M - Medium
H - High

Soil Property Rating

1 - Low
2 - Medium
3 - High

Landforms	Generalized Soil Texture	Cut Design						Embankment Files					Embankment Foundation			Highway Subgrade				Foundation Design					Miscellaneous		
								Compacted Materials												Shallow Footings		Piles					
		Soil Backslope Stability	Rock Backslope Stability	Groundwater Control	Erosion	Surface Drainage	Natural Slope and River Banie Stability	Erosion	Relative Permeability	Shear Strength	Compressibility When Saturated	Workability	Settlements	Shear Strength	Organic Matter	Subgrade Support	Frost Action	Pumping	Shrink-Swell	Bearing Capacity	Settlements	Bearing Capacity	Settlements	Negative Skin Friction	Shallow Residential Septic Systems	Steel Corrosivity	Concrete Corosion
Alluvial Terrace	Silt and Clay	M		M/H	M	L	L	M	2	M/H	M/H	L/M	H	L/M	M/H	L	L/M	L/M	L	H/M	H/M	L/M	M	L/M	L/M	L/M	M
Flood Plains (Alluvial Plain)	Sand, Silt, gravel	M		M/H	M/H	L	M	M	3	M	M	L/M	M/H	L/M	M/H	L	L/M	M	L	M	M	M	M	L/M	H/M	L/M	M
Residual Sandstone-Shale-Limestone Upland	Silt and Clay	M		M	M	M	M	L/M	1-2	M	L/M	M	M	M	L/M	M	M/H	M	L	L/M	M	M/L	L/M	M	M/H	M	L/M
Residual Sandstone-Shale Sideslopes	Silt, Clay and trace of rock	M/H		M	M/H	L	L	H	1-2	M	L/M	M/H	M	M	L/M	M	M/H	M/H	L	M	M	M	M	M	M/H	L/M	L/M
Residual Sandstone-Shale Bedrock Benches	Silt, Clay and rock Fragments	M/H		M	M	L	L	M/H	1-2	M	L/M	M/H	M	M/H	L/M	M	M	M	L	M	M	M	L/M	M	M/H	M	L/M
Residual Limestone Uplands	Silt, Clay-Loam	M/H		L	L	M	L	M/H	1-2	M	M	M/H	M/H	L/M	L/M	L/M	L/M	M/H	H	M/H	M/H	M/H	H/M	M/H	M/H	M	L/M
Residual Limestone Sideslope	Silt, Clay and rock fragments	M/H		M	M/H	M/H	M	H	1-2	M	M	M/H	M/H	M	L/M	L/M	M	M/H	H	M/H	M/H	M/H	H/M	M/H	M/H	M/H	L/M
Residual Limestone Bedrock Benches	Silt, Clay, rock fragments	M/H		M		M	L	M	1	M	M	M/H	M/H	M	L/M	L/M	M	M	M	M/H	M/H	M/H	M	M	M/H	M/H	L/M
Rock Sandstone-Shale	Rock	M	L	L	L	M	L	L	1	L	L	L	L	L	L	L/M	L/M	L	L	L	L/M	L/M	L/M	L/M		L/M	L/M
Limestone	Rock	H	M	L	L	H	L/M	L	1	L	L	L	L/M	L	L	L/M	M	L	L	M/H	M/H	L/M	M/H	L/M		M	L

Site specific data, obtained from a carefully planned detailed exploration program is required for any design project. The report and preliminary engineering soil map serve as a guide for planners and designers of highways, dams, bridges, and foundations in the preliminary stages of their work.

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APPENDIX A1. Boring and Laboratory Data for SR 37 Over Hogs Defeat Creek (14).

Boring No.	Sample No.	Highway Route No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil Description		Blow per Ft.	Recovery	RQD	Grain Size Distribution				LL	PL	PI
							Texture	AASHTO				Gravel	Sand	Silt	Clay			
RB-2(1)*	1	SR 37	2607+00	70LT.	599.1	1- 2.5	Silty loam with trace sandstone fragments	A-4	3	60								
	2					3.5-5	Silty loam with some gravel/sand.	A-2-4	4	65								
	3	SR 37	2607+00	70LT.		6-7	Weathered Shale	--	56	100								
			Auger Refusal at 8.0 ft.					--										
RB-6(2)	1	SR 37	3607+90	45LT.	599.1	1- 2.5	Soft Silty Loam	A-4	3	65								
	2	SR 37	3607+90			3.5-5	Stiff Silty Loam	A-2-4	21	30								
	3	SR 37	3607+90			6-7.5	Soft Clay Loam	A-6(9)	5	40								
	4	SR 37	3607+90			8.5-10	Sandy Loam with trace of rock fragments	A-6(3)	2	100								
			Auger Refusal at 11.5 ft.															
S-3(3)	1	SR 37	2608+68	25LT.	600.0	0-5	Sandy Loam with trace of rock fragments	--										
	2	Auger refusal at 6.5				5-6.5	Soft silty clay	--										
	3					6.5-11.5	Soft weathered Shale	--		56	38	Auger Refusal at 11.5 ft.						
	4					11.5-21.5	Dolomite with inter-bedded limestone	--		90	84							

* Numbers enclosed in parentheses correspond to borehole number on the Engineering Soil Map prepared for this report. The preceding numbers are used in the source reports.

APPENDIX A1. Continued.

Boring No.	Sample No.	Highway Route No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil Description		Blow per Ft.	Recovery	RQD	Grain Size Distribution				LL	PL	PI
							Texture	AASHTO				Gravel	Sand	Silt	Clay			
S-4(4)	1	SR 37	2608+62	23LT.		0-1.0	Sand Gravel	--										
	2	SR 37	2608+62			1-2.5	Silty clay Loam with rock fragments	--										
	3	SR 37	2608+62			2.5-6.5	Silty loam	--										
	3	Auger Refusal at 9.0 ft.				6.5-9.0	Sandy Shale	--										
	4					9-9.8	Fossiliferous Limestone	--		96	60							
TB-2(5)	1	SR 37	2608+36	23RT.	596.6	1-1.7	Loose Sand and gravel	--	60	70								
	1	SR 37	2608+36	23RT.		2.5-7	Hard Limestone	--		56	0							
	2	SR 37	2608+36	23RT.		10.2-14.7	Dolomite interbedded with fossilferous	--		89								
						14.7-19.7	Limestone	--		86								
TB-3(6)	1	SR 37	2608+44	23LT.	599.5	1-2.5	Sandy Loam and Gravel	A-2-4	3	80								
	2	SR 37	2608+44	23LT.	399.3	2.5-5	Stiff Silty Loam	A-2-4	10	70								
	3	SR 37	2608+44	23LT.	399.3	6-11	Soft Weathered Shale	--		40	6							
	4		2608+44	23LT.	399.3	11-16	Hard Dolomite interbedded with Limestone	--		90	62							
	5		2608+44			16-21	Limestone	--		78	50							
TB-4(7)	1	SR 37	2608+91	23RT.	600.6	1-2.5	Silty Loam with sandstone fragments	A-4	2	65								
	2	SR 37	2608+91	23RT.		3.5-5	Soft Silty Loam	A-2-4	6	55								

APPENDIX A1. (Continued).

Boring No.	Sample No.	Highway Route No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil Description		Blow per Ft.	Recovery	RQD	Grain Size Distribution				LL	PL	PI
							Texture	AASHTO				Gravel	Sand	Silt	Clay			
	3	SR 37				6-7.5	Stiff Silty Loam	A-2-4	30	70								
	4	SR 37				7.5-8.5	Weathered Shale	--										
	5	SR 37				8.5-10	Sandy Loam	A-6										
	6	SR 37				10.5-15.5	Fossiliferous Limestone	--		47	26							
	7	SR 37				15.5-25.9	Weathered Shale Limestone, interbedded	--		100	44							
	8	SR 37				15.5-25.9	with fractured dolomite	--		100	32							
S-2(8)	1	SR 37	2608+14	25 LT.	600.7	1-4	Stiff Silty Loam with rock fragments	--										
						4-8.5	Sandy Loam with rock fragments	--										
						8.5-13.5	Dolomite interbedded with Limestone	--		84	60							
								Auger Refusal at 8.5'										
						13.5-18.9	Dolomite interbedded with Limestone			56	28							
PT-1(9)	1	SR 37	2608+00	55 LT.		1-2	Silty Loam	A-4(2)	3	65								
	2	SR 37	2608+00			6-8	Sandy loam with gravel	A-2-4(0)	1									
	3	SR 37	2608+00			10-12	Silty Clay	Dropped under self weight	0									

APPENDIX A1. (Continued).

Boring No.	Sample No.	Highway Route No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil Description		Blow per Ft.	Recovery	RQD	Grain Size Distribution				LL	PL	PI
							Texture	AASHTO				Gravel	Sand	Silt	Clay			
PT-2(10)	1	SR 37	2606+05	7.0 LT.	599.5	1-3	Loam	A-6(5)	4	100		6.1	32.7	42.7	18.5	30.0	17.4	124
	2					3-5	Sandy Loam	A-2-4	6	50								
	3					6-7	Clay Loam	A-6(9)	10	100		10.5	20.9	48.3	20.3	33.6	18.1	15.5
	4					8-10	Silty Clay	--	2	50								
TB-1(11)	1	SR 37	2607+78	40 LT.	599.5	1-2.5	Silty Loam	A-4	1	70								
	2					3.5-5	Silty Loam	A-4	5	80								
	3					6-7.5	Silty Loam	A-4	6	80		28.0	38.3	24.9	8.8	26.2	18.7	7.5
	4					8.5-10	Silty Loam with some gravel	A-2-4(0)	9	50								
	5					13.5-15	Sandy Loam	A-6(3)	3	75								
	6					18.5-19	Sandy Loam	A-6(3)	50	60								
	8					20-25	Dolomite inter-bedded with some Limestone with some trace of chert	--		100	58							
	9					25-30	Dolomite inter-bedded with some Limestone with some trace of chert	--		66	96							
TB-1A(12)	1	SR 37	2608+04	12 RT.	600.2	1-2.5	Soft Silty Loam	A-4(2)	3			0.4	35.7	51.7	12.2	25.8	18.6	7.2
						3.5-5	Sandy Loam and Gravel	A-2-4(0)	11			39.5	28.0	23.7	8.8	29.3	19.0	10.3
12						6-7.5	Sandy Loam and Gravel	A-2-4(0)	1									
						7.5-9.5	Silty Clay very Soft											
						9.5-11.5	Sandy Loam	A-6(3)	0	100		16.5	35.0	33.0	15.5	28.9	16.1	12.8
						11.5-15	dropped 3.5 under weight of rods		0									
						15-30	Limestone inter-bedded with dolomite			100								

Appendix A2

Boring and Laboratory Data
For S.R. 145 in Patoka Reservoir Area

Boring No.	Sample No.	Highway Route No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil Description		Blow per Ft.	Recovery	RQD	Grain Size Distribution				LL	PL	PI
							Texture	AASHTO				Gravel	Sand	Silt	Clay			
B-1(13)	1	SR. 145	311+00	15R.	595.4	0-0.5	Silty Clayloam trace of Organics											
	2					0.5-8.0	Clay	A-7-6(26)				7	7	35	50	46.6	16.1	30.6
						8-12.0	Weathered Shale and Clay	--										
						12.5-2.3	Limestone	--		100								
B-2(14)	1	SR. 145	311+00	95R.	620.6	0-0.5	Silty Clayloam	--										
	2	SR. 145				0.5-2.0	Sandy loam and some gravel	A-4(0)				25	34	24	17	24.0	14.8	9.2
	3	SR. 145				2.0-4.0	Sandy loam and some gravel	A-4(0)										
	4	SR. 145				4-5.0	Weathered Shale and Sandstone			94								
	5	SR. 145				5-19.8	Weathered Shale Sandy & Sandstone			90								
B-3(15)	1	SR. 145	318+00	60L.	579.3	0-1.0	Silty Clay loam		5									
	2	SR. 145				1.0-2.0	Silty Clay and some sandstone fragments	A-6										
	3	SR. 145				2.5-4.00	Silty Clay and some sandstone fragments		29									
	4	SR. 145				5-7.0	CLAY	A-7-6(25)				10	15	29	46	51.7	17.7	34.0
	5	SR. 145				7-8.5	CLAY											
	6	SR. 145				10-11.5	Weathered Shale with Clay		31									

Appendix A2 continued

Boring No.	Sample No.	Highway Route No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil Description		Blow per Ft.	Recovery	RQD	Grain Size Distribution				LL	PL	PI
							Texture	AASHTO				Gravel	Sand	Silt	Clay			
	7	SR. 145				12.5-14	Weathered Shale with Clay											
	8	SR. 145				15-16	Silty Clay	A-6	5									
			Refusal at 16.0 ft															
B-8 (16)	1	SR. 145	335+25	20R.	622.5	0-0.2	Silty Clay Loam and little Organic											
	2	SR. 145	335+25	20R.	622.5	0.2-4.5	Loam	A-6(5)				18	16	49	17	30.1	19.4	10.7
		Refusal at 4.5																
B-26(17)	1	SR. 145	413+71	461RT.	621.0	0-2	Silty Clay	A-6										
	2	SR. 145	413+71	461RT.		2-4	Clay	A-7-6(24)				9	12	28	51	4619	15.8	31.1
	3	SR. 145	413+71	461RT.		4-14	Weathered Shale Clay											
	4					14-18	Limestone and Weathered Shale			66								
B-28(18)	1	SR. 145	425+82	300RT.	641.1	0-0.5	Silty Clay Loam and trace of Organics											
						0.5-1.5	Silty Clay	A-6										
						1.5-2.0	Clay and Sandstone fragments	A-7-6										
						2.0-6.0	Clay	A-7-6(27)				0	7	39	54	50.7	24.8	25.9
B-32(19)	1	SR. 145	438+10	45RT.	668.3	0-1	Silty Clay Loam											
						1-2	Silty Clay Loam											
						2-4.5	Silty Clay	A-6				13	14	43	27	33.2	16.7	17.1
						4.5-6.0	Clay	A-7-6										
BS-1(20)	1	SR. 145	400+01	25LT.	545.7	0-0.5	Loam											
						0.5-4.5	Clay Loam											
						4.5-9.5	Weathered Sandstone											
BS-3(21)	1	SR. 145	401+63	25LT.	521.9	0-1.5	Silty Clay Loam & trace of Organics											
						1.5-4.0	Clay Loam	A-6										
						4-7	Silty Clay	A-6										
						4.7-11.5	Limestone Interbedded with Siltstone			58								

Appendix A3

Boring and Laboratory Data for Sinclair Street Bridge Over French Lick Creek (16)

Boring No.	Sample No.	Highway Route No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil Description		Blow per Ft.	Recovery	RQD	Grain Size Distribution				LL	PL	PI
							Texture	AASHTO				Gravel	Sand	Silt	Clay			
TB-1 (22)	1	Sinclair St. French Lick	41+02	15RT.	489.9	3.5-5.0	Loam with Limestone Fragments	A-6(5)	4	35								
			Encountered boulders at 1 ft.															
	2	Sinclair St. French Lick	41+02	15RT.	489.9	6-7.5	Loam with Limestone Fragments	A-6(5)	16	100								
	3	Sinclair St.	41+02	15RT.	489.9	13.5-18.5	Loam (soft) with trace of Wood fibes	A-4	2	80								
	4	Sinclair St.	41+02	15RT.	489.9	18.5-20.2	Stiff Loam	A-6	13	100								
			Auger refusal at 20.2 ft.															
	5					20.2-25.0	Weathered, fine to med. grained limestone			38	27							
	6					25-30.2	Weathered, fine to med. grained limestone			88	18							
TB-2 (23)	1	Sinclair St. French Lick	41+30	LT.	474.5	0-5.5	Loam with little Organic Leaves	A-6	3	85								
	2	Sinclair St. French Lick	41+30	LT.	474.5	5.5-8.3	Loam with Limestone Fragments	--	18	100								
	3	Sinclair St. French Lick	41+30	LT.	474.5	8.3-13.3	Fine grained Limestone	--		78	23							
			Auger Refusal at 8.3 ft., Water level after 24 hours = 0.0 (i.e. dry)															
TB-3 (24)	1	Sinclair St. French Lick	41+85	11RT.	483.0	0-5.5	Loam	A-6	4	60								
	2	Sinclair St. French Lick	41+85	11RT.	483.0	5.5-12.5	Loam	A-4(1)	3	75								

Appendix A3 Cont'd

Boring No.	Sample No.	Highway Route No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil Description		Blow per Ft.	Recovery	RQD	Crain Size Distribution				LL	PL	PI
							Texture	AASHTO				Gravel	Sand	Silt	Clay			
	3	Sinclair St. French Lick	41+85	11RT.	483.0	12.5-16.6	Clay (Weathered limestone)	A-6	50	100								
						16.6-21.5	Weathered Limestone		?	100								
			Refusal at 15.6 ft. Water level after 24 hours = 5.7 ft.															
TB-4 (25)	1	Sinclair St. French Lick	42+20	8.5LT.	482.8	0.5-3.0	Loam	A-6	7	60								
						3.0-13	Loam	A-4	3									
			Auger refusal at 13.21															
TB-5 (26)	1	Sinclair St. French Lick	42+67	11RT.	483.7	0-3.0	Loam soft	A-6	5	75								
	2	Sinclair St. French Lick	42+67	11RT.	483.7	3.0-5.5	Loam very soft	A-4	3	65								
	3	Sinclair St. French Lick	42+67	11RT.	483.7	5.5-8.0	Stiff Loam	A-6	6	75								
	4	Sinclair St. French Lick	42-67	11RT.	483.7	8.0-11.5	Loam	A-4	6	80								
			Auger refusal at 11.51															
	5	Water level after 24 hours 5.9 ft.				11.5-16.0	Med. Grained Limestone			86	5							
RB-1 (27)	1	Sinclair St. French Lick	43+50	12RT.	479.4	1-8.0	Silty Loam	A-6(16)	6	95								
	2					8.0-11.5	Stiff Clay	A-6(16)	11	80								
			Auger refusal at 11.5 ft															
						11.5-16.5	Weathered Limestone		84	13								
			Water level after 24 hours = 4.0 ft.															
TB-15 (28)						1-13.5	Loam with Limestone Fragments	A-6(5)	8									
						13.5-18.5	Loam with trace of wood fibres	A-4	13									
TB-55 (29)			Same as boring No. 26															

Appendix A4: Boring and Laboratory Data for US-150 over No Name Creek (20)

Boring No.	Sample No.	Highway Route No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil Description		Blow per Ft.	Recovery	RQD	Grain Size Distribution				LL	PL	PI
							Texture	AASHTO				Gravel	Sand	Silt	Clay			
TB-1(30)	3	US-150	542+00	30LT.	578.1	1-10	Silty Clay	A-6(18)	21	100								
RB-2(31)	1	US-150	545+60	73RT.	574.4	0-1	Sand and Gravel											
RB-2(31)	2	US-150		73RT.		1-5.5	Silty Clay Medium Stiff		8	100								
	3	US-150	545+60	73RT.		5.5-8.0	Silty Loam Stiff Moist	A-6	12	100								
	4		545+60	73RT.		8-14	Silty Clay hard, medium stiff	A-6	10									
		Auger refusal at 14.0 ft.																
RB-3(32)	1	US-150	551+00	52RT.	582.5	0-1	Sand and Gravel											
	2					1-8	Silty Loam	A-6(19)	6	100		0.0	3.2	78.6	18.2	31	10	21
	3					8-10.5	Silty Clay moist, brown	A-6	8									
		Auger refusal at 10.5																
TB-2(33)	1	US-150	545+46	23RT.	568.1	0.5-3.0	Clay		7	100								
	2	US-150				3.0-8.0	Silty Clay Loam	A-4(5)	7									
	3	US-150				8-13	Limestone			96	51							
TB-3(34)	1	US-150	546+60	23LT.	567.0	0.5-3.0	Silty Clay		9	100								
	2					3.0-8.0	Loam	A-6(12)	20	90		1.5	29.6	49.2	19.7	27	3	24
	3					8.0-13.0	Limestone			94	80							
		Auger refusal at 8.0																
TB-4(35)	1	US-150	546+06	23RT.	567.8	0.4-3.0	Clay		6	100								
	2	US-150				3.0-8.5	Silty Clay Loam	A-4	14	100								
	3					8.5-13.5	Limestone			90	38							

Appendix B Engineering Properties of Agricultural Soils of Orange County

Soil Name and Map Symbol	Depth (in)	USDA Text	Classification		Frags > 3in (%)	Percent Passing Sieve #				LL %	PI %	Clay (%)	Wet Density (g/cm^3)	Permeability (in/hr)	Soil React. (pH)	Srink/ Swell Potential
			USCS	AASHTO		#4	#10	#40	#200							
Ba --- Bartle	0-9	Sil	CL, CL-ML	A-4, A-6	0	100	100	85-100	65-90	20-35	5-15	15-26	1.30-1.45	0.6-2.0	5.1-7.3	Low
	9-25	SiL-SiCL	CL, CL-ML	A-4, A-6	0	100	100	90-100	70-90	25-35	5-15	22-35	1.40-1.60	0.6-2.0	4.5-5.5	Low
	25-44	SiL, SiC	CL,	A-6, A-7	0	100	100	90-100	70-90	30-45	10-25	22-35	1.60-1.80	<0.06	4.5-5.5	Low
	44-60	SiCL, Sil	CL	A-6, A-7	0	100	100	90-100	70-95	30-45	10-25	22-35	1.40-1.60	0.2-0.6	4.5-7.3	Low
BdA, BdB- Bedford	0-10	SiL ...	CL, ML	A-6, A-4	0	100	100	95-100	85-95	30-40	5-15	10-16	1.30-1.45	0.6-2.0	3.6-7.3	Low
	10-29	SiL, SiCl	CL	A-6, A-7	0	100	95-100	95-100	85-95	25-45	15-25	24-32	1.30-1.45	0.6-2.0	3.6-5.5	Moderate
	29-65	SiL, SiC	CL	A-6, A-7	0	100	95-100	95-100	85-95	25-45	15-25	25-35	1.50-1.70	<0.06	3.6-5.5	Moderate
	65-80	SiC, CL SiCl	CL, CH	A-7	0-5	90-100	75-95	70-95	65-90	45-55	20-30	35-60	1.30-1.50	0.2-0.6	3.6-5.5	Moderate
Br ---- Bromer	0-9	SiL	ML, CL-ML	A-4, A-6	0	100	95-100	90-100	85-100	20-35	3-13	10-18	1.25-1.40	0.6-2.0	5.1-7.3	Low
	9-43	SiL, SiCl	CL-ML, CL	A-6, A-4	0	100	95-100	90-100	85-100	25-40	6-20	20-32	1.40-1.6	0.6-2.0	4.5-5.5	Moderate
	43-56	SiCL, SiL	CL	A-4, A-6 A-7	0	95-100	90-100	85-100	75-95	30-45	9-25	22-34	1.40-1.60	0.06-0.2	4-5-6.0	Moderate
	56-80	SiC, C Chty.C Vchty C	CH, SC CL, SC	A-6, A-7 A-6, A-7 A-2	0-5	40-70	30-70	25-70	25-65	35-60	15-35	45-80	1.40-1.65	0.06-0.2	5.6-7.3	High
BU ---- Burnside	0-12	SiL	ML, CL, CL-ML	A-4	0-10	100	100	80-95	75-95	20-35	2-10	15-27	1.20-1.40	0.6-2.0	4.5-6.0	Low
	12-64	ChL, VCh- SaL, Fig SiL	SC, GC, SM, GM	A-2, A-4	10-60	35-80	30-60	30-50	20-45	<20	NP-10	14-25	1.40-1.60	0.6-2.0	4.5-6.0	Low
CaD3 --- Caneyville	0-2	SiCL	CL	A-6	0-3	90-100	85-100	75-100	65-100	30-40	11-20	27-40	1.20-1.40	0.6-2.0	4.5-7.3	Low
	2-24	C, SiC,	CH	A-7	0-3	90-100	85-100	75-100	65-100	50-75	30-45	40-60	1.35-1.60	0.2-0.6	5.6-7.8	Moderate
	24	UWBR.	--	--	--	--	--	--	--	--	--	--	--	--	--	--
CaD3: Crider--	0-4	Sil	ML, CL CL-ML	A-4, A-6	0	100	95-100	90-100	85-100	25-35	4-12	15-27	1.20-1.40	0.6-2.0	5.1-7.3	Low
	4-27	SiL, Si CL	CL, ML, CL-ML	A-7, A-6 A-4	0	100	95-100	95-100	85-100	24-42	4-20	18-35	1.20-1.45	0.6-2.0	5.1-7.3	Low
	27-62	SiC, C, SiCL	CL, CH	A-7, A-6	0-5	85-100	75-100	70-100	60-100	35-65	15-40	30-60	1.20-1.55	0.6-2.0	4.5-6.0	Moderate

* See list of abbreviations on last page of Appendix B.

APPENDIX B. (Continued)

Soil Name and Map Symbol	Depth (in)	USDA Text	Classification		Frags > 3in (%)	Percent Passing Sieve #				LL %	PI %	Clay (%)	Wet Density (g/cm^3)	Perme-ability (in/hr)	Soil React. (pH)	Srink/ Swell Potential
			USCS	AASHTO		#4	#10	#40	#200							
CaE Caneyville	0-10	SiL	ML, CL CL-ML	A-4, A-6	0-3	90-100	85-100	75-100	60-95	20-35	2-12	10-25	1.20-1.40	0.6-2.0	4.5-7.3	Low
	10-20	SiL,SiC C	CH, CL	A-7	0-3	90-100	85-100	75-100	65-100	42-90	20-45	25-60	1.35-1.60	0.2-0.6	4.5-7.3	Moderate
	20-29	C,SiC	CH	A-7	0-3	90-100	85-100	75-100	65-100	50-75	30-45	40-60	1.35-1.60	0.2-0.6	5.6-7.8	Moderate
	29	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--
CaE: Crider -	0-13	SiL	ML, CL CL-ML	A -4,A-6	0	100	95-100	90-100	85-100	25-35	4-12	15-27	1.20-1.40	0.6-2.0	5.1-7.3	Low
	13-30	SiL,Si CL	CL,ML CL-ML	A-7,A-6 A-4	0	100	95-100	90-100	85-100	25-42	4-20	18-35	1.20-1.45	0.6-2.0	5.1-7.3	Low
	30-63	SiC,C SiCL	CL,CH	A-7,A-6	0-5	85-100	75-100	70-100	60-100	35-65	15-40	30-60	1.20-1.55	0.6-2.0	4.5-6.0	Moderate
CaF Caneyville	0-5	StSiL	ML,CL	A-4,A-6	5-30	90-100	85-100	75-100	60-95	20-35	2-12	10-25	1.20-1.40	0.6-2.0	4.5-6.0	Low
	5-14	SiC,C SiCL	CH,CL	A-7	5-30	90-100	85-100	75-100	65-100	42-70	20-45	36-60	1.35-1.60	0.2-0.6	4.5-6.0	Moderate
	14-26	C,SiL	CH	A-7	5-30	90-100	85-100	75-100	65-100	50-75	30-45	40-60	1.35-1.60	0.2-0.6	5.6-7.8	Moderate
	26	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rock Outcrop																
CrB, CrC2 Crider	0-9	SiL	ML,CL	A-4,A-6	0	100	95-100	90-100	85-100	25-35	4-12	15-27	1.20-1.40	0.6-2.0	5.1-7.3	Low
	9-45	SiL, SiCL	CL,ML CL-ML	A-7,A-6 A-4	0	100	95-100	90-100	85-100	25-42	4-20	18-35	1.20-1.45	0.6-2.0	5.1-7.3	Low
	45-80	SiC,C, SiCL	CL,CH	A-7,A-6	0-5	85-100	75-100	70-100	60-100	35-65	15-40	30-60	1.20-1.55	0.6-2.0	4.5-6.0	Moderate
C_2C_3 Crider	0-3	SiL	ML,CL	A-4,A-6	0	100	95-100	90-100	85-100	25-35	4-12	15-27	1.20-1.40	0.6-2.0	5.1-7.3	Low
	3-45	SiL, SiCL	CL,ML,CL-ML	A-7,A-6, A-4	0	100	95-100	90-100	85-100	25-42	4-20	18-35	1.20-1.05	0.6-2.0	5.1-7.3	Low
	45-66	SiL,C, SiCL	CL,CH	A-7,A-6	0-5	85-100	75-100	70-100	60-100	35-65	15-40	30-60	1.20-1.55	0.6-2.0	4.5-6.0	Moderate
CuD_2: Crider -	0-6	SiL	ML, CL	A-4,A-6	0	100	95-100	90-100	85-100	25-35	4-12	15-27	1.20-1.40	0.6-2.0	5.1-7.3	Low
	6-25	SiL, SiCL	CL,ML,CL-ML	A-7,A-6, A-4	0	100	95-100	90-100	85-100	25-42	4-20	18-35	1.20-1.45	0.6-2.0	5.1-7.3	Low
	25-70	SiC,C, SiCL	CL,CH	A-7,A-6	0-5	85-100	75-100	70-100	60-100	35-65	15-40	30-60	1.20-1.55	0.6-2.0	4.5-6.0	Moderate

APPENDIX B (Continued)

Soil Name and Map Symbol	Depth (in)	USDA Text	Classification		Frags > 3in (%)	Percent Passing Sieve #				LL %	PI %	Clay (%)	Wet Density (g/cm^3)	Permeability (in/hr)	Soil React. (pH)	Shrink/ Swell Potential
			USCS	AASHTO		#4	#10	#40	#200							
Caneyville	0-6	SiL	ML, CL, CL-ML	A-4, A-6	0-3	90-100	85-100	75-100	60-95	20-35	2-12	10-25	1.20-1.40	0.6-2.0	4.5-7.3	Low
	6-18	SiL, C, SiCl	CH, CL	A-7	0-3	90-100	85-100	75-100	65-100	42-70	20-45	36-60	1.35-1.60	0.2-0.6	4.5-7.3	Moderate
	18-36	C-SiC	CH	A-7	0-3	90-100	85-100	75-100	65-100	50-75	30-45	40-60	1.35-1.60	0.2-0.6	5.6-7.8	Moderate
	36	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--
CXC2: Crider	0-9	SiL	ML, CL CL-ML	A-4, A-6	0	100	95-100	90-100	85-100	25-35	4-12	15-27	1.20-1.40	0.6-2.0	5.1-7.3	Low
	9-25	SiL, SiCL	CL, ML, CL-ML	A-7, A-6 A-4	0	100	95-100	90-100	85-100	25-42	4-20	18-35	1.20-1.45	0.6-2.0	5.1-7.3	Low
	25-80	SiC, C, Chty-SiCL	CL, CH	A-7, A-6	0-5	85-100	75-100	70-100	60-100	35-65	15-40	30-60	1.20-1.55	0.6-2.0	4.5-6.0	Moderate
Frederick	0-6	SiL	ML, CL CL-ML	A-4, A-6	0-5	80-100	75-100	75-100	75-90	< 35	NP-15	13-23	1.25-1.50	2.0-6.0	4.5-6.0	Low
	6-19	SiL, SiCL	CL, CL-ML	A-6, A-7	0-5	80-100	60-100	55-100	50-95	20 45	5-25	20-40	1.40-1.65	0.6-2.0	4.5-6.0	Moderate
	19-80	C, CL, SiL	CH, ML-CH	A-7	0-5	90-100	85-100	70-100	60-95	60-85	30-55	50-85	1.40-1.65	0.6-2.0	4.5-5.5	High
Caneyville	0-4	Silt loam	ML, CL CL-ML	A-4, A-6	0-3	90-100	85-100	75-100	60-95	20-35	2-12	10-25	1.20-1.4	0.6-2.0	4.5-7.3	Low
	4-12	SiC, C, SiCL	CH, CL	A-7	0-3	90-100	85-100	75-100	65-100	42-70	20-45	36-60	1.35-1.6	0.2-0.6	4.5-7.3	Moderate
	12-32	C, SC	CH	A-7	0-3	90-100	85-100	75-100	65-100	50-75	30-45	40-60	1.35-1.6	0.2-0.6	5.6-7.8	Moderate
	32	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--
ElA, ElB, ElC2 Elkinsville	0-10	SiL	CL, CL-ML	A-4, A-6	0	100	100	90-100	70-90	25-40	5-15	15-26	1.30-1.45	0.6-2.0	5.6-7.3	Low
	10-36	SiCL, SiL	CL	A-6, A-4	0	100	100	85-100	65-90	30-40	8-18	22-30	1.40-1.60	0.6-2.0	4.5-6.0	Moderate
	36-59	SiCL, L, SaCL	CL	A-4, A-6	0	100	100	80-100	50-90	30-40	8-18	16-30	1.45-1.65	0.6-2.0	4.5-5.5	Moderate
	59-80	St2.CL, SaL	CL, CL-ML ML, SM	A-4, A-6	0	100	100	70-100	45-80	< 30	NP-15	20-34	1.40-1.60	0.6-2.0	4.5-6.0	Low

APPENDIX B (Continued)

Soil Name and Map Symbol	Depth (in)	USDA Text	Classification		Frags > 3in (%)	Percent Passing Sieve #				LL %	PI %	Clay (%)	Wet Density (g/cm^3)	Perme-ability (in/hr)	Soil React. (pH)	Srink/ Swell Potential
			USCS	AASHTO		#4	#10	#40	#200							
FrD2,FrF	0-6	Sil	ML, CL, CL-ML	A-4,A-6	0-5	80-100	75-100	75-95	75-90	<35	NP-15	13-23	1.25-1.50	2.0-6.0	4.5-6.0	Low
Frederick	6-19	Sil, SiCl, Chty SC	CL-CL-ML	A-6,A-7	0-5	80-100	60-100	55-100	50-95	20-45	5-25	20-40	1.40-1.65	0.6-2.0	4.5-6.0	Moder-ate
	19-80	C,CL, SiL	CH,ML-CH	A-7	0-5	90-100	85-100	70-100	60-95	60-85	30-55	50-85	1.40-1.65	0.6-2.0	4.5-5.5	High
GOF: Gilpin	0-7	SiL	CL,CL-ML	A-4,A-6	0-5	80-95	75-90	70-85	65-80	20-40	4-15	15-27	1.20-1.40	0.6-2.0	3.6-5.5	Low
	7-32	ChL, SiCL	GC,SC, CL,CL-ML	A-2,A-4, A-6	0-30	50-95	45-90	35-85	30-80	20-40	4-15	18-35	1.20-1.50	0.6-2.0	3.6-5.5	Low
	32	UNBR.	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Wellston	0-5	SiL	ML	A-4	0	95-100	90-100	85-100	70-95	25-35	3-10	13-27	1.3 -1.50	0.6-2.0	5.1-6.5	Low
	5-27	SiL, SiCL	CL,CL-ML	A-6,A-4	0-5	75-100	70-100	60-95	60-90	25-40	5-20	18-35	1.30-1.05	0.6-2.0	4.5-6.0	Low
	27-72	SiL,CL, ChL	CL-ML, CL,CH, SC,SM-SC	A-4,A-6, A-7	0-10	65-90	65-90	60-90	40-65	20-35	5-15	15-40	1.30-1.60	0.6-2.0	4.5-6.0	Low
	72-81	WBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hd Haymond	0-9	SiL	ML	A-4	0	100	100	90-100	80-90	27-36	4-10	10-18	1.30-1.45	0.6-2.0	5.6-7.3	Low
	9-40	SiL	ML	A-4	0	100	100	90-100	80-90	27-36	4-10	10-18	1.30-1.45	0.6-2.0	5.6-7.3	Low
	40-60	FSaL, SiL,L	ML,SM	A-4	0	95-100	95-100	80-100	35-90	27-36	4-10	10-18	1.30-1.45	0.6-2.0	6.1-7.3	Low
Mo Montgomery	0-19	SiCL	CL	A-7	0	100	100	100	85-100	40-50	20-30	35-40	1.35-1.55	0.2-0.6	6.1-7.8	High
	19-69	SiCL, SiL	CH	A-7	0	100	100	95-100	90-100	50-65	30-42	40-55	1.45-1.65	<0.2	6.1-8.4	High
	69-80	St C, SiCL	CL,CH	A-7	0	100	100	90-100	85-100	40-55	20-32	35-60	1.50-1.70	<0.2	7.4-8.4	Moder-ate

APPENDIX B (Continued)

Soil Name and Map Symbol	Depth (in)	USDA Text	Classification		Frags > 3in (%)	Percent Passing Sieve #				LL %	PI %	Clay (%)	Wet Density (g/cm^3)	Permeability (in/hr)	Soil React. (pH)	Srink/ Swell Potential
			USCS	AASHTO		#4	#10	#40	#200							
PeB, PeC2	0-7	SiL	CL, CL-ML	A-4, A-6	0	100	100	85-100	65-100	20-30	5-15	15-26	1.30-1.45	0.6-2.0	5.6-7.3	Low
Pekin	7-20	SiL, SiCL	CL	A-6	0	100	100	90-100	70-100	25-40	10-20	25-35	1.40-1.60	0.6-2.0	4.5-5.5	Low
	20-43	SiL, SiCL	CL, CL-ML	A-4, A-6	0	100	100	88-98	65-90	25-35	5-15	22-30	1.60-1.80	<0.06	4.5-5.5	Low
	43-60	St fSaL SiCL	CL, CL-ML	A-4, A-6	0	100	100	80-95	50-95	20-40	5-15	20-34	1.40-1.60	0.6-2.0	4.5-7.3	Low
Po	0-13	SiL	ML, CL-ML	A-4, A-6	0	100	95-100	90-100	70-95	20-35	3-11	12-22	1.25-1.40	0.6-2.0	5.1-7.3	Low
Peoga	13-38	SiL, SiCL	CL-ML, CL	A-6, A-4	0	100	95-100	90-100	70-95	25-40	6-20	22-34	1.40-1.60	0.6-2.0	4.5-6.5	Low
	38-80	SiC, ChtyC, VChtyC	GC, CL, CH	A-7, A-2-7	0-5	45-75	35-75	30-75	30-70	40-65	15-40	45-80	1.40-1.65	0.06-0.2	4.5-7.3	High
Pt.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pits	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ud.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Udorthents	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Wa Wakeland	0-9	SiL	ML	A-4	0	100	100	90-100	80-90	27-36	4-10	10-17	1.30-1.50	0.6-2.0	5.6-7.3	Low
	9-60	SiL	ML	A-4	0	100	100	90-100	80-90	27-36	4-10	10-17	1.30-1.50	0.6-2.0	5.6-7.3	Low
WeC2, We, C3 Wellston	0-8	SiL	ML	A-4	0	95-100	90-100	85-100	70-95	25-35	3-10	13-27	1.30-1.50	0.6-2.0	5.1-6.5	Low
	8-46	SiL, SiCL	CL, CL-ML	A-6, A-4	0-5	75-100	70-100	60-95	60-90	25-40	5-20	18-35	1.30-1.65	0.6-2.0	4.5-6.0	Low
	46-50	SiL, CL CHL	CL-ML, CL, SC, SM-SC	A-4, A-6	0-10	65-90	65-90	60-90	40-65	20-35	5-15	15-40	1.30-1.60	0.6-2.0	4.5-6.0	Low
	50	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--

APPENDIX B (CONTINUED)

Soil Name and Map Symbol	Depth (in)	USDA Text	Classification		Frags > 3in (%)	Percent Passing Sieve #				LL %	PI %	Clay (%)	Wet Density (g/cm^3)	Permeability (in/hr)	Soil React. (pH)	Srink/ Swell Potential
			USCS	AASHTO		#4	#10	#40	#200							
WfD3: Wellston	0-1	SiL	ML	A-4	0	95-100	90-100	85-100	70-95	25-35	3-10	13-27	1.30-1.50	0.6-2.0	3.1-6.5	Low
	1-25	SiL, SiCL	Cl, CL-ML	A-6,A-4	0-5	75-100	70-100	60-95	60-90	25-40	5-20	18-35	1.30-1.65	0.6-2.0	4.5-6.0	Low
	25-44	SiL,SiCL,ChL	CL-ML,CL SC,SM-SC	A-4,A-6	0-10	65-90	65-90	60-90	40-65	20-35	5-15	15-35	1.30-1.60	0.6-2.0	4.5-6.0	Low
	44	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
WfD3: Ebal --	0-1	SiCL	CL-ML, CL	A-4,A-6	0	95-100	95-100	90-100	80-98	25-40	5-15	27-35	1.35-1.5	0.6-2.0	4.5-6.0	Low
	1-9	ChSiL, SiCL	CL,SC	A-6,A-7	0-3	60-70	50-70	45-70	40-65	30-45	12-20	20-30	1.40-1.60	0.6-2.0	4.5-6.0	Moderate
	9-19	ChSiL; SiCL,C	CL,CH SC	A-7	3-15	60-70	50-70	45-70	35-65	40-55	20-30	38-50	1.45-1.65	0.2-0.6	4.5-6.0	Moderate
	19-58	C	CH	A-7	0-3	95-100	90-100	80-100	70-95	60-75	35-45	55-70	1.55-1.75	<0.06	4.5-6.0	High
	58-68	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gilpin	0-1	SiL	CL,CL-ML	A-4,A-6	0-5	80-95	75-90	70-85	65-80	20-40	4-15	15-27	1.20-1.40	0.6-2.0	3.6-5.5	Low
	1-22	ChL,ChSiL, SiCL	GC,SC,CL CL-ML	A-2,A-4 A-6	0-30	50-95	45-90	35-85	30-80	20-40	4-15	18-35	1.20-1.5	0.6-2.0	3.6-5.5	Low
	22	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--
WgD2: Wellston	0-7	SiL	ML	A-4	0	95-100	90-100	85-100	70-95	25-35	3-10	13-27	1.30-1.50	0.6-2.0	5.1-6.5	Low
	7-46	CL,SiL, SiCL	CL,CL-ML	A-6,A-4	0-5	75-100	70-100	60-95	60-90	25-40	5-20	18-35	1.30-1.65	0.6-2.0	4.5-6.0	Low
	46-72	SiL,Ch Sa-CL, ChL	CL-ML,CL SC,SM-SC	A-4,A-6	0-10	65-90	65-90	60-90	40-65	20-35	5-15	15-30	1.30-1.60	0.6-2.0	4.5-6.0	Low
	72	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--

APPENDIX B. (Continued)

Soil Name and Map Symbol	Depth (in)	USDA Text	Classification		Frags > 3in (%)	Percent Passing Sieve #				LL %	PI %	Clay (%)	Wet Density (g/cm^3)	Perme-ability (in/hr)	Soil React. (pH)	Srink/ Swell Potential
			USCS	AASHTO		#4	#10	#40	#200							
Gilpin	0-6	SiL	CL, CL-ML	A-4, A-6	0-5	80-95	75-90	70-85	65-80	20-40	4-15	15-27	1.20-1.40	0.6-2.0	3.6-5.5	Low
	6-28	ChL, ChSiL, SiCL	GC, SC, CL, CL-ML	A-2, A-4, A-6	0-30	50-95	45-90	35-85	30-80	20-40	4-15	18-35	1.20-1.50	0.6-2.0	3.6-5.5	Low
	28	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--
EbaL	0-6	SiL	CL-ML, CL	A-4, A-6	0	95-100	95-100	90-100	80-98	25-40	5-15	20-28	1.35-1.50	0.6-2.0	4.5-6.0	Low
	6-16	ChSiL, SiL SiCL	CL, GC	A-6, A-7	0-3	60-70	50-70	45-70	40-65	30-45	12-20	20-35	1.40-1.60	0.6-2.0	4.5-6.0	Moderate
	16-75	ChSiC, SiCLC	CL, CH, GC	A-7	3-15	60-70	50-70	45-70	35-65	40-55	20-30	38-60	1.45-1.65	0.2-0.6	4.5-6.0	Moderate
	75	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--
WgD2:	0-8	SiL	ML, CL-ML	A-4	0	100	100	90-100	70-90	<25	3-7	10-17	1.30-1.45	0.6-2.0	5.6-7.3	Low
Wr Wilbur	8-60	SiL	ML, CL-ML	A-4	0	100	100	90-100	70-90	<25	3-7	10-17	1.30-1.45	0.6-2.0	5.6-7.3	Low
ZaA, ZaB	0-8	SiL	CL-ML, CL	A-4, A-6	0	95-100	95-100	90-100	50-100	25-40	4-15	12-27	1.35-1.40	0.6-2.0	4.5-5.5	Low
Zanesville	8-25	SiL, SiCL	CL, CL-ML	A-4, A-6	0	95-100	95-100	90-100	80-100	25-40	5-20	18-35	1.35-1.45	0.6-2.0	4.5-5.5	Low
	25-43	SiL, SiCL	ML, CL, CL-ML	A-4, A-6	0-3	90-100	85-100	80-100	60-100	20-40	2-20	18-33	1.50-1.75	0.06-0.6	4.5-5.5	Low
	43-56	ChC, SaLL, CL, ChSaLL	SC, CL, SM, GM	A-6, A-4, A-2, A-1-6	0-10	65-100	50-95	40-95	20-85	20-40	2-20	20-50	1.50-1.70	0.2-2.0	4.5-5.5	Low
	56	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--
ZaC2, ZaC3	0-9	SiL	CL-ML, CL, ML	A-4, A-6	0	95-100	95-100	90-100	80-100	25-40	4-15	12-27	1.35-1.40	0.6-2.0	4.5-5.5	Low
Zanesville	9-25	SiL, SiCL	CL, CL-ML	A-4, A-6	0	95-100	95-100	90-100	80-100	25-40	5-20	18-35	1.35-1.45	0.6-2.0	4.5-5.5	Low
	25-43	SiL, SiCL	ML, CL, CL-ML	A-4, A-6	0-3	90-100	85-100	80-100	60-100	20-40	2-20	18-33	1.50-1.75	0.06-0.6	4.5-5.5	Low

APPENDIX B. (Continued)

Soil Name and Map Symbol	Depth (in)	USDA Text	Classification		Frags > 3in (%)	Percent Passing Sieve #				LL %	PI %	Clay (%)	Wet Density (g/cm^3)	Permeability (in/hr)	Soil React. (pH)	Shrink/ Swell Potential
			USCS	AASHTO		#4	#10	#40	#200							
	43-58	SiC,L, CL, ChSaCL	GC,CL, SM,GM	A-6,A-4, A-2, A-1-b	0-10	65-100	50-95	40-95	20-85	20-40	2-20	20-50	1.50-1.70	0.2-2.0	4.5-5.5	Low
	58	UWBR	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Abbreviations:

Texture: C - Clay
Si - Silt
Sa - Sand
L - Loam

f - fine
vf - very fine
ch - channery
Vch - very channery

sh - shaly
vsh - very shaly
VB - Weathered bedrock
UWBR - Unweathered bedrock
gr - gravelly
str - stratified
chty - cherty
st - stonny

APPENDIX C 1

RECORD OF SOIL EXPLORATION SR 37 (24)

District Offices: Indianapolis/Chicago
Baltimore-Washington/Cincinnati/Louisville/Atlanta

CLIENT Indiana State Highway Commission
BORING NO. TB 1
PROJECT NAME S-180(2) SR 37 Str.# 37-59-6196
JOB NO. E-7504 DATE 1-30-75 2-3-75
PROJECT LOCATION Sta 2495+88.75 23'Rt of Line "D" Orange Co. IN
FOREMAN R.Hackman INSPECTOR D.Chase
BORING METHOD HSA & RC RC DIA. 2 1/8 in.
SHELBY TUBE O.D. ______ in.

⊗ UNCONFINED COMPRESSIVE STRENGTH, TSF 1 2 3 4 5
○ NATURAL DRY DENSITY, PCF 90 100 110 120 130
☐ WATER CONTENT, % ◩ LIQ. LIM., % ◪ PLAST LIM., % 10 20 30 40 50
● STANDARD PENETRATION, BLOWS/FT. 10 20 30 40 50

SOIL CLASSIFICATION SURFACE ELEVATION – 562.5 *	STRATUM DEPTH, FT.	GROUND WATER	DEPTH SCALE, FT.	SPT* SAMPLE NO.	SPT* BLOWS/6 in. INCREMENTS	SPT* RECOVERY, %	SHELBY TUBE NO.
Brown moist loose to very loose Clay Loam				1	2 3/3	100	
A-4 #2	5.5		5	2	2 1/2	30	
Brown moist loose Sandy Loam A-4 #1 w/some Sandstone frags.	8.0			3	3 5/5	40	
Brown moist medium stiff Clay Loam A-4 #2 with some rock fragments	9.3		10	4	3/50/ 0.3/-	100	
Gray hard Limestone	14.3			5	RC	100	
Bluish-Gray Argillaceous Limestone Breccia (broken from 15.0-15.1')	15.8		15	6	RC	94	
Gray hard Limestone (Brecciated from 19.5 to 22.0-also with thin argillaceous streaks)	24.3		20	7	RC	100	
Bottom of test boring 24.3' * Elevation obtained by hand level.			25				

BORING METHOD
HSA – HOLLOW STEM AUGER
CFA – CONTINUOUS FLIGHT AUGER
DC – DRIVEN CASING

GROUND WATER
▽ NOTED ON RODS ______ FT.
▼ AT COMPLETION 5.5 FT.
▼ AFTER 24 HRS 6.5 FT.

SHELBY TUBE SAMPLES OBTAINED IN BORING ______ DRILLED A FEW FEET FROM BORING ______

APPENDIX C2

RECORD OF SOIL EXPLORATION SR 37 (24)

District Offices: Indianapolis/Chicago
Baltimore-Washington/Cincinnati/Louisville/Atlanta

CLIENT Indiana State Highway Commission
PROJECT NAME S-180(2) SR 37 Str.# 37-59-6196
PROJECT LOCATION Sta 2498+41.25 23' Lt of Line "D" Orange Co. IN
FOREMAN R.Hackman INSPECTOR D.Chase
BORING METHOD HSA & RC RC DIA. 2 1/8 in.
SHELBY TUBE O.D. ______ in.
BORING NO. TB 4 see also TB 4-A5
JOB NO. E-7504 DATE 2-6-75

⊗ UNCONFINED COMPRESSIVE STRENGTH, TSF 1 2 3 4 5
○ NATURAL DRY DENSITY, PCF 90 100 110 120 130
☐ WATER CONTENT, % ▨ LIQ. LIM., % ▨ PLAST. LIM., % 10 20 30 40 50
● STANDARD PENETRATION, BLOWS/FT. 10 20 30 40 50

SOIL CLASSIFICATION SURFACE ELEVATION — 564.5 *	STRATUM DEPTH, FT.	GROUND WATER	DEPTH SCALE, FT.	SPT* SAMPLE NO.	SPT* BLOWS/6in. INCREMENTS	SPT* RECOVERY, %	SHELBY TUBE NO.
Reddish Brown moist loose Clay Loam A-4 #2	3.0			1	4 5/4	40	
Reddish Brown moist stiff Clay A-7-6 #5			5	2	6 5/6	60	
Sandstone fragments 6-6.5'				3	3 4/5	70	
Boulder 7.5-8.9 ft	8.9						
Bottom of test boring 8.9'			10				

*Elevation obtained by hand level.

Auger refusal at 7.5' - on a boulder

Went in with core barrel to 8.9' through soil beside boulder

No core recovery.

Abandoned hole and offset to Sta 2498+44 23' Lt and auger went down crooked against a boulder at 3± feet.

Moved to Sta 2498+41 26' Lt and auger went in crooked against a boulder at 3± ft again.

Moved to Sta 2498+41 29' Lt and had auger refusal at 5.5

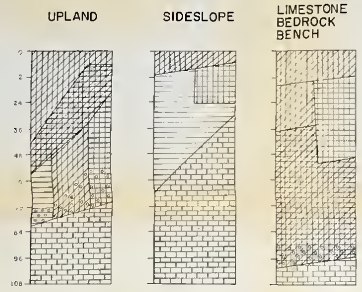
Moved to Sta 2498+41' 20 ' Lt and had auger refusal on a boulder at 4.5' Cored through 1.1' thick boulder into a void (See Boring B-4-A_4)

Moved to Sta 2498+36 20' Lt for Boring TB 4-A_5 and cored fifteen ft. (See Boring B-4-A_5)

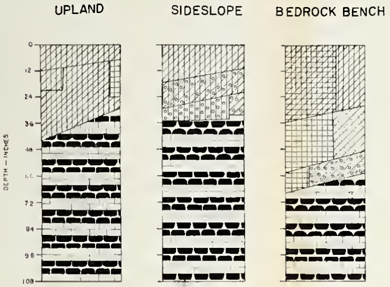
JHRP 85/19 [illegible]

GENERAL SOIL PROFILES

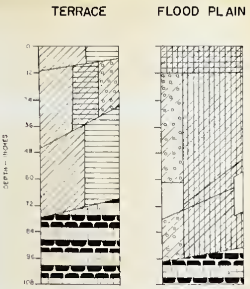
RESIDUAL LIMESTONE PLAIN

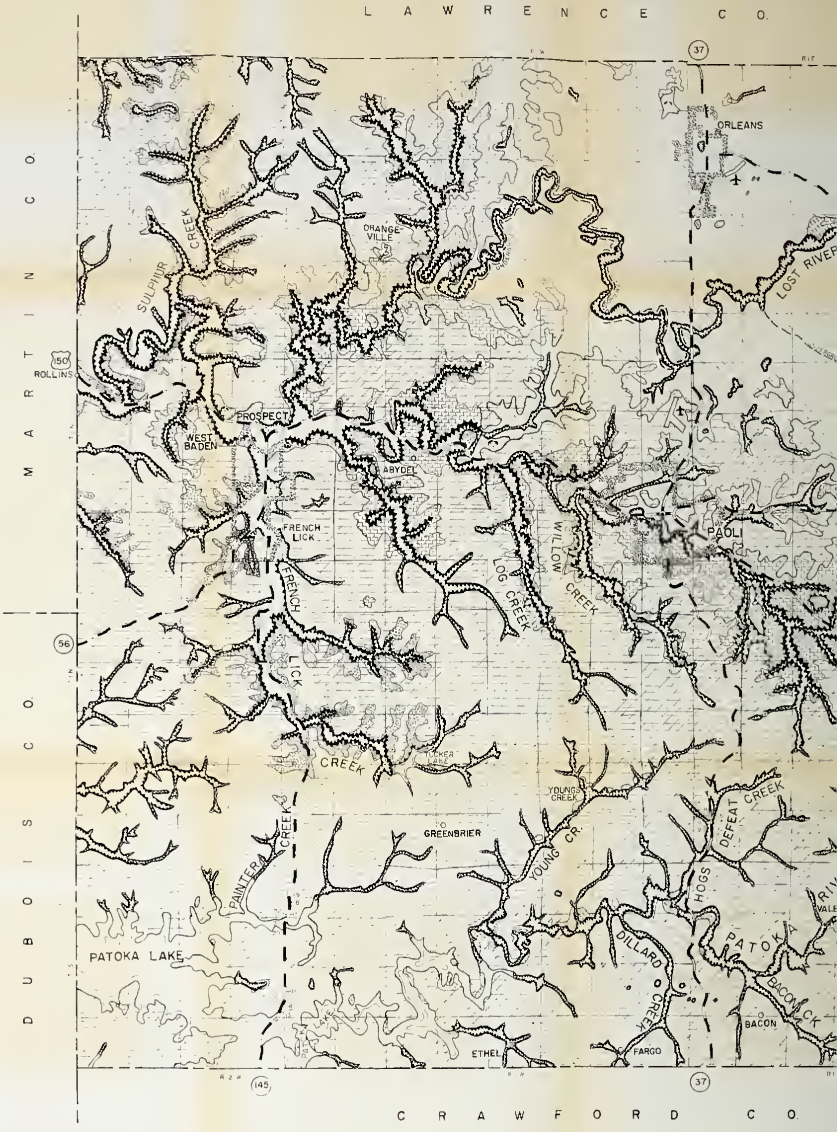


RESIDUAL SANDSTONE-SHALE PLATEAU

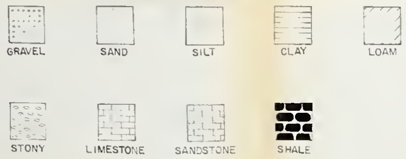


FLUVIAL DEPOSITS





TEXTURAL SYMBOLS FOR SOIL PROFILES



ENGINEERING SOILS MAP
ORANGE COUNTY
INDIANA

PREPARED BY

JOINT HIGHWAY RESEARCH PROJECT

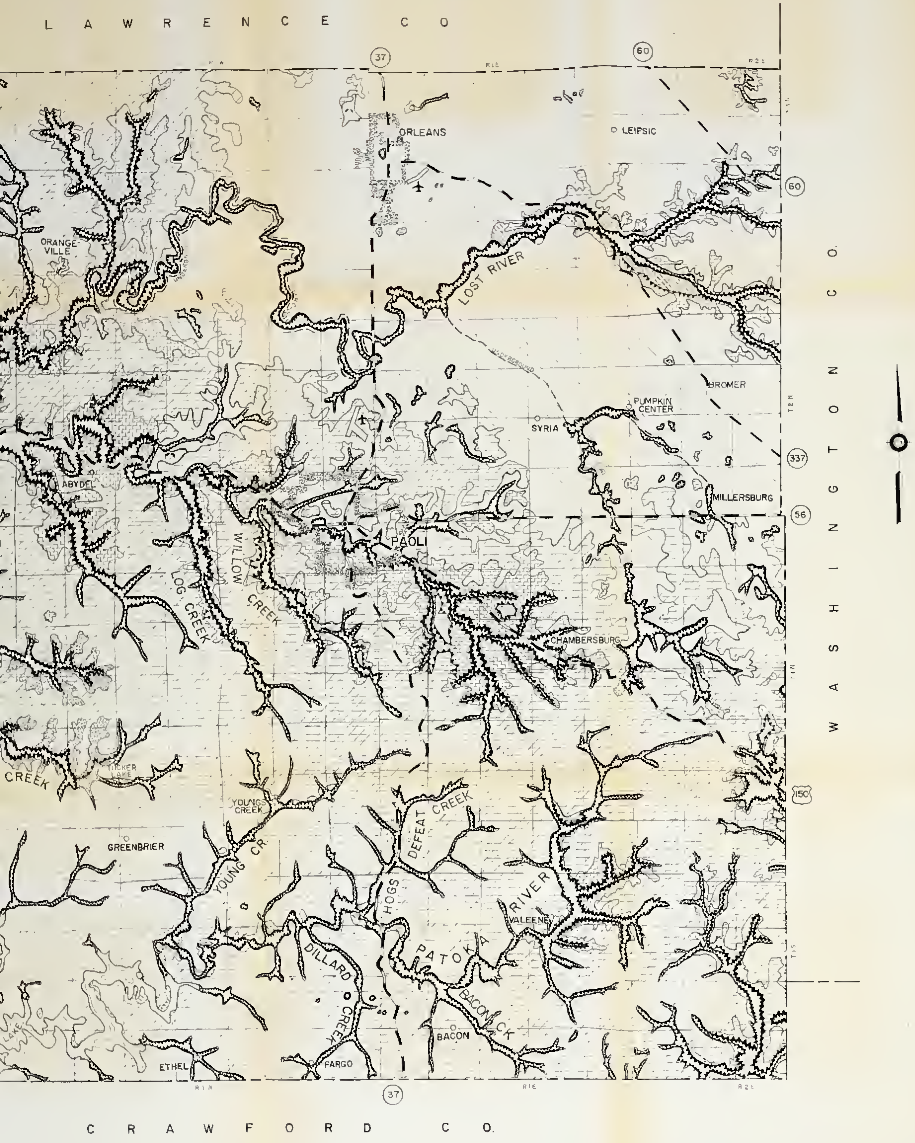
AT

PURDUE UNIVERSITY

1985

SCALE OF MILES

PREPARED UNDER THE SUPERVISION OF I O OKONKWO AND R D MILES



LEGEND

PARENT MATERIALS

GROUPED ACCORDING TO LAND FORM AND ORIGIN

- ▨ LIMESTONE PLAIN
- ▤ INTERBEDDED SANDSTONE AND SHALE PLATEAU
- SANDSTONE-SHALE LIMESTONE BENCH
- LIMESTONE BENCH
- FLOOD PLAIN
- ▨ TERRACE

MISCELLANEOUS

- LIMESTONE QUARRY
- LAKE, POND, OR RESERVOIR
- DAM
- URBAN AREA
- MAJOR AIRPORT
- BORING SITES

TEXTURAL SYMBOLS

(SUPERIMPOSED ON PARENT MATERIAL TO SHOW RELATIVE COMPOSITION)

- GRAVEL
- SAND
- SILT
- CLAY

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SCALE OF MILES

DRAWN BY XIAOGONG WANG